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Cape Town, South Africa

March 29 - April 2, 1982

by

United States of America National Committee
for Representation of the United States to the
International Association on Water Pollution Research and Control

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Donald E. Carey
Project Officer

Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C.

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16. ABSTRACT

This report is not simply a collection of papers or abstracts of papers presented at the Eleventh International Conference on Water Pollution Research held in Cape Town, South Africa on March 29 - April 2, 1982, but it is an analysis of formal and informal developments including pertinent remarks, comments and ideas brought out in discussions of papers and with researchers from throughout the world.

Included in this report are reviews of the Poster Sessions and interpretive analyses of informal developments at the Conference which were judged to be relevant to water quality control activities in the United States.

Formal papers and discussions of the Conference have been published as Proceedings in Water Science and Technology.

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Mr. Donald E. Carey
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Re: EPA Grant No. R809703-01-1

Dear Mr. Carey:

In accordance with the provisions of EPA Grant No. R809703-01-1, awarded to the United States of America National Committee (USANC) for representation of the U.S. to the International Association on Water Pollution Research and Control (IAWPRC), USANC is pleased to transmit this report entitled "Developments at Eleventh International Conference on Water Pollution Research". Included in this report are reviews of the Poster Sessions and interpretive analyses of informal developments at the Conference which were judged to be of particular relevance to water quality control activities in the U.S. A total of thirty-four (34) engineers and scientists from the U.S. contributed in some way to the preparation of this report.

The purpose of the EPA Grant, resulting in this report, was to provide a mechanism whereby current water research developments from around the world could be highlighted and brought to the attention of the EPA Office of Research and Development and other U.S. water pollution researchers. Specifically, this report is not simply a collection of papers presented at the Conference in Cape Town, South Africa, March 29 - April 12, 1982, or merely an abstract or synopsis of papers, but rather an analysis of formal and informal developments, including pertinent remarks, comments and ideas brought out in discussions of papers and with researchers from throughout the world; representatives from twenty-nine (29) different countries attended the Conference. The formal papers and discussions of the Conference are published as Proceedings in Water Science and Technology.

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AMERICAN INSTITUTE OF CHEMICAL ENGINEERS AMERICAN SOCIETY OF CIVIL ENGINEERS WATER POLLUTION CONTROL FEDERATION

12TH BIENNIAL INTERNATIONAL CONFERENCE, AMSTERDAM, NETHERLANDS, 17-20 SEPTEMBER 1984

The members of USANC sincerely appreciate the support provided by the Office of Research and Development for the preparation of this report. Should there be any questions or need for additional information, please feel free to contact any member of the Coordinating Subcommittee.

Sincerely,

Frederick G Pohland

for USANC Coordinating Subcommittee

R. S. Engelbrecht
R. A. Conway
D. G. Stephan
F. G. Pohland, Chairman

hb

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*Note: This presentation was included in the program but was not presented at the Conference. It is not included in this report.

EXECUTIVE SUMMARY

Beginning in 1962, the International Association on Water Pollution Research and Control has held an international conference biennially. This report is an interpretative analysis of formal and informal developments at the Eleventh International Conference on Water Pollution Research held in Cape Town, South Africa on March 29 to April 2, 1982 and has been prepared for the U.S. Environmental Protection Agency by the U.S.A. National Committee for Representation of the United States to the International Association on Water Pollution Research and Control.

Conference papers, complete with formal and informal floor discussion, are published in *Water Science and Technology*. Because of this, this report does not contain the formal papers or verbatim presentations of discussions. Rather, this report was prepared by the official United States participants in the Conference as a critical analysis of formal and informal developments at the Conference which were deemed to be of potential interest to U.S. water pollution researchers.

Important information concerning developments in international water pollution research was obtained both from the formal Conference sessions, and, perhaps even more importantly, from informal information exchanged outside the formal meeting rooms. Of particular significance were the following:

-- the use of a thermally-modulated electron capture detector with a gas chromatograph to identify haloacetylnitriles and trihalomethanes in drinking water (U.S.A).

-- the control of cercariae of human schistosomes with slow sand filtration (U.S.A.).

-- the recovery of PVA from a textile wastewater with an ultrafiltration system (South Africa).

-- the potential use of magnetic ion exchange resins and macroporous resins in a continuous countercurrent ion exchange process to demineralize wastewater and brackish water (Australia, South Africa).

-- the roles of turbulence and diffusion in nutrient transport in fixed-film biological processes (Denmark, France, Japan, Thailand, U.S.A.).

-- the widespread use of fixed-film systems, especially rotating biological contactor systems, throughout Europe and Africa.

-- installation of rotating biological contactors in primary sedimentation tanks to improve treatment performance (U.S.A.).

-- the independent and concurrent development and evaluation of single-sludge, biological, nitrification-denitrification systems (Japan, South Africa).

-- the removal of nitrogen, phosphorus and other algal growth stimulants in a two-stage, high-rate algal treatment system (Israel).

-- the potential for use of rheological measurements to control sludge conditioning processes (Canada).

-- pasteurization of raw sludges using submerged combustion of digester gas (Federal Republic of Germany).

-- the economical use of thermophilic aerobic digestion over anaerobic digestion for sludge stabilization (Federal Republic of Germany).

-- the resistance of *Ascaris* ova to inactivation in sludge treatment (South Africa).

-- regulation of landspreading of sludges based on absence of E. *coli*, *Ascaris* ova and pathogenic viruses (South Africa).

-- the use of a hamster-cell transformation assay to measure carcinogens and toxicants in reclaimed wastewater and drinking water (South Africa).

-- the need to evaluate the effects of microbial adaptation and mutation on the use of indicator microorganisms (Japan, U.S.A.).

-- the role of adsorption on ultrafiltration membranes, aluminum hydroxide flocs and glass powders in removal of enteroviruses (Brazil, France, U.S.A.).

- -- the continuing interest in use of ozone to modify structure of nonbiodegradable compounds to biodegradable end products (U.S.A., South Africa).
- -- the stimulation of bacterial regrowth in drinking water by residual organic matter following ozonation (Switzerland).
- -- the need to incorporate atmospheric deposition rates and improve upon water quality prediction capabilities of SWMM models for urban runoff (South Africa).
- -- increasing importance of including internal nutrient sources in nutrient balances used to study lake eutrophication.
- -- the release of phosphorus from surficial sediments to lake water resulting from anaerobic destruction of insoluble ferric iron compounds (U.S.A.).
- -- the use of three coal gasification plants by the South African Coal, Oil and Gas Corporation, SASOL, to meet approximately 20% of the petroleum needs of the country (South Africa).
- -- the use of biological oxidation, carbon adsorption and ion-exchange processes to reclaim wastewaters at SASOL plants for industrial reuse (South Africa).
- -- concentration of coal-gasification wastewater effluents using cooling towers and brine disposal to coal-ash piles (South Africa).
- -- the expanding development and testing of fluidized bed, expanded bed and fixed-film/suspended-film systems for biological treatment of carbonaceous and nitrogenous materials (United Kingdom, South Africa).
- -- a demonstration study on the Simon-Hartley Captor process using porous pieces of plastic in an aeration tank to increase biomass concentration and enhance removal of carbonaceous organic matter (United Kingdom).
- -- the importance of anaerobic conditions to the growth of *Acinetobacter* and successful application of biological phosphorus-removal systems.
- -- the negative impact of low COD/TKN ratios, lack of anaerobic conditions and presence of nitrate-nitrogen on biological phosphorus removal systems (South Africa).

- improved biological phosphorus removal by using long sludge ages due to internal accumulation of chemically-precipitated phosphorus in mixed liquor (South Africa).

- the reappearance of *Vibrio cholerae* along the Southern coast of the United States and the Natal coast of South Africa; antibiotic-resistant cholera is endemic throughout most of Africa (U.S.A., South Africa).

- the development of a small, disposable gas chromatograph for use in performing field analyses (South Africa).

- the use of biological denitrification in Paris for treatment of drinking water (France).

CHAPTER I

INTRODUCTION

BACKGROUND

The International Association on Water Pollution Research and Control (IAWPRC) is a non-governmental professional organization with the goal of advancing water pollution research worldwide to enhance the quality of the earth's water resources. Through conferences, workshops, symposia, and publications, e.g., *Water Research* and *Water Science and Technology*, IAWPRC provides a means for the international communication of research results and new information relative to water quality control. The organization is governed by representatives of national committees of member countries. Each national committee, as a condition of membership in IAWPRC, represents the water quality research-related activities in the respective country; currently, 29 countries are members of IAWPRC.

The United States of America National Committee (USANC) is recognized by IAWPRC as the national organization representing United States water quality research interests in IAWPRC. USANC is sponsored by five major professional organizations with interests in water quality research: (1) American Chemical Society; (2) American Institute of Chemical Engineers; (3) American Society of Civil Engineers; (4) Association of Environmental Engineering Professors; and (5) Water Pollution Control Federation. Each of these professional organizations provides a modest amount of financial support to USANC for membership in IAWPRC and appoints two delegates and two alternate delegates to serve on USANC.

An international conference, sponsored by IAWPRC, has been held biennially since 1962. Prior to the Eleventh International Conference in Cape Town, South Africa, March 29 - April 2, 1982, conferences were held in London, Tokyo, Munich, Prague, San Francisco, Jerusalem, Paris, Sydney, Stockholm and Toronto. The 1984 Conference is scheduled for Amsterdam, The Netherlands, September 17-20, 1984; Rio de Janiero has been nominated as the site of the Thirteenth Conference in 1986. The conferences represent the largest international gathering of research engineers and scientists, consulting engineers, manufacturers of process control equipment, administrators of water quality control programs and others involved in water quality control.

The purpose of this report, prepared by USANC for the Office of Research and Development, U.S. Environmental Protection Agency, is not to present a verbatim record of the Conference. Papers, and workshop and poster presentations, complete with formal and informal floor discussion and responses from authors, have been published as a Proceedings in a professional journal of IAWPRC ("Water Pollution Research and Control: Parts 1-4." *Water Science and Technology*, *14*, 4/5, 1-406; *14*, 6/7, 407-794; *14*, 8, 795-1044; *14*, 9/11, 1045-1614 (1982)). Rather, the purpose of the report is to present a timely and critical analysis of formal and informal developments at the Conference which are of potential interest to EPA. The report represents an assessment by United States participants in the Conference of the significant developments at the Conference. Contributions of individual authors from various countries of the world are considered in the context of the reception which they received from discussers and the international audience. The analysis is not limited to formal conference developments, but includes developments from the informal exchanges between engineers and scientists from various countries which inevitably occur at such conferences outside of the formal sessions.

The technical program for the Cape Town Conference was developed by the Program Committee of IAWPRC from papers submitted from around the world in response to an invitation to submit papers covering a wide range of subjects, e.g., the ecology of natural waters, limnology, micropollutants, fish toxicology, marine and estuarine pollution, runoff from agricultural and urban areas, treatment of municipal and industrial wastewaters, and sludge treatment. Reprints of papers selected for the program were available to participants in advance of the Conference, and only abbreviated summaries of the papers were presented by the authors in Cape Town. Formal discussers were selected prior to the Conference to prepare critical analyses of each paper. Additionally, appreciable informal discussion of the papers and of the formal discussions occurred. Appendix I contains the program for the Conference and provides additional information on the conduct of the sessions.

REPORT DEVELOPMENT

This report was prepared by those United States participants in the Cape Town Conference who presented papers, presented formal discussions of research work described by others, chaired or recorded sessions and workshops, and participated in IAWPRC

Governing Board activities and who elected to participate in the project. Development of the report was coordinated by a Subcommittee of USANC consisting of USANC officers for 1980-1982 (F. G. Pohland, Chairman; R. S. Engelbrecht, Vice-Chairman; R. A. Conway, Secretary-Treasurer) and D. G. Stephan.

Prior to the Conference, the USANC Coordinating Subcommittee ascertained the interest of Conference participants in contributing to the development of this report and solicited expressions of interest in reviewing particular sessions at the Conference (Appendix II). Assignments for coverage of all the sessions were then made as indicated in Appendix III. Appendix IV contains the instructions given to participants for the development of this report.

Reports by the individual participants are included in Chapter II. Aside from minor editing to render the reports compatible with the general format and to eliminate items unrelated to water quality research, the reports are published here as received from the authors. Thus, the reports represent a critical assessment by United States water quality control researchers and other professionals of those sessions of the Conference which received their special attention. The individual reports appear under the by-line of the reviewers and represent their personal views--not necessarily the views of the Coordinating Subcommittee or USANC.

Highlights of Chapter II, as perceived by the Coordinating Subcommittee, are summarized in Chapter III. In addition, information submitted by individual participants on developments at the Conference unrelated to their sessions are summarized in Chapter III. The Executive Summary is an abbreviated version of Chapter III.

Users of the report will find the Table of Contents together with the Key to Reviews useful in locating in Chapter II the discussions of particular papers, workshops or poster presentations. Additionally, Appendix I should be useful in gaining a perspective on the Conference and on the contents of Chapter II.

CHAPTER II

CONFERENCE SESSION REPORTS

I. SESSION

A. Day: Monday, March 29, 1982
Hall: A
Time: 11:45 a.m. to 12:00 p.m.

B. Theme of Session: Monitoring Systems and Strategies, Buoyant Jets, Taste and Odors

II. REVIEWER

A. Name: Betty H. Olson

B. Position and Affiliation: Associate Professor of Social
Ecology, Environmental Analysis
University of California
Irvine, CA (U.S.A.)

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 1: "The Effect of Submarine Wastewater Discharge on the Bacterial Quality of Surf Water," by D. J. Livingstone (South Africa)

Livingstone (South Africa) discussed the impact of the introduction of wastewater treatment and discharge lines for sewage coming from several areas along the Durban coast. The main thrust of the paper was the use of a microbiological scheme for rating the occurrence of *Escherichia coli* 1, parasite units, *Staphlococcus* and salmonellae and salinity. This numerical scheme was used to evaluate surf water quality before and after the construction of two submarine outfalls. It was noted that a significant improvement in the quality of the surf of the bathing beaches occurred after the operation of the outfalls began.

Livingstone (South Africa) described the central area of Durban before the construction project which then processed approximately 90,000 m^3/d of wastewater in 1964. In the vicinity of the harbor, wastewater was temporarily stored after screening and discharged with the outgoing tide at the mouth of the harbor entering the sea. Outside the harbor to the south, approximately 20,000 m^3/d was injected into the surf via an outfall. In addition, there were numerous minor discharges along the sea coast.

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Factors of major concern in this study were two outfalls, one located at the central works at the harbor of Durbin and the other located at the southern works adjacent to the Umlaas Canal. The pipe line at the central works was 3.2 km long and that at the southern works was approximately 4.2 km in length. The diffuser section was 421.8 m long for both pipes. The discharge-line diameter at the central works was 1.22 m while at the southern works it was 13.7 m. The average discharge from the diffuser at the central works was 77,400 m^3/d and at the southern works was 72,000 m^3/d.

A monitoring scheme was developed which allowed the examination of bathing beaches prior to and after the initiation of treatment. Further, sampling areas also included sites which would show background levels of pollution which came from sources other than sewage, such as rainwater runoff or streams and rivers entering the surf zone.

Importantly, this paper considered the oceanographic and current dynamics of the area. Although the main current is southwardly, topography and the subsequent movement of the Agulhas current inshore result in a flow along the shelf in a generally northward direction. The near-shore currents tend to flow parallel to this course and reverse direction in association with atmospheric pressures every one to three days.

The author demonstrated a marked improvement in water quality after the installation of treatment and discharge lines by applying his indicator system as follows; bathing beaches were divided into four categories: (1) good; (2) fair; (3) poor; and (4) very poor. These categories were assigned indicator values: 1-4 would be classified as good, 5-8 would be classified as fair, 9-16 as poor, and greater than 16 very poor or a "category 4" quality of seawater.

A summation of the work can be stated in the fact that during the period of 1964 and 1965, category 1 waters accounted for 5 of the samples, category 2 accounted for 8, category 3 for 10 and category 4 for 5 samples. Again in 1967 before discharging via the pipe, the average for all 26 sampling stations was category 1 beaches accounted for 3, category 2 beaches accounted for 6, category 3 beaches accounted for 12, and category 4 beaches accounted for 7.

The sewage treatment plant and the discharge pipes at the southern works began operation in 1968 and at the central works in 1969. Sampling done in 1970 showed a remarkable change in quality parameters; 16 of the sampling stations were classified as category 1, while 6 were category 2, 4 were category 3 and 2 were category 4. The importance of a diffuser line was observed when treatment failure occurred at the central works in 1970. Even though untreated effluent was being discharged, the quality of the bathing beaches remained good with 18 of the 26 beaches classified as good. It is important to note that at several sampling stations, water quality did not improve with the construction of sewage lines for deep ocean discharge, the reason being that many pathogens or indicator organisms were being washed into the surf area through drainage ditches, canals or river flows which enter the surf zone. This is an important point made by the paper. Sewage treatment and ocean discharge may be excellent at removing inputs from citywide sources or those sources directly linked to the sewage treatment plant, but in areas where bathing beaches are exposed to open drainage and where these drainage areas can be impacted by various types of fecal pollution, either from human or animal sources, then degradation of quality will occur around those areas regardless of sewage treatment.

Olson (U.S.A.), the official discusser, stated that the work clearly indicated the importance of marine outfalls in decreasing onshore microbial pollutants as well as the impact of nonpoint sources in the microbiological degradation of marine bathing beaches. Her discussion focused on three areas: technical, theoretical and practical aspects of the classification approach.

Regarding technical issues, Olson (U.S.A.) pointed out that the sampling procedures appeared to not adequately address (1) wind direction, (2) current reversals, and (3) wave action, which can dramatically affect results. No reference was given as to time of day of sampling which had been established as important in determining bathing beach quality. Further, she pointed out the importance of designating where in the water column a sample is taken, as it can have a public health significance. She also stated that time of year is important due to intensity of beach use. Lastly and importantly, the need to know the quality of effluent should be addressed as it represents the maximum load of organisms released with a potential to reach shore. Frequency of sampling must, in addition, be addressed if statistical analyses are to applied to the data.

Regarding theoretical issues, the epidemiological relationship between an evaluative water quality scheme and the indicator or pathogen of importance is a difficult topic. Nevertheless, it should always be considered. The relationship of the designated scheme and its health significance is difficult to ascertain. Thus, the concept of dilution must be tempered by concentration (i.e., shellfish) depending on the source of exposure and the exposed population.

Pathogen dose, route of entry and virulence should be considered. Therefore, an indicator system must incorporate organisms which are short-lived in sea water (i.e., *Salmonella*, *Shigella*, *Staphlococcus*, *Taenia* or *Ascaris*) as well as those which mimic longer-lived pathogens (i.e., *V. cholerae* or viruses). Optimally, the indicator system should also be applicable to shellfish.

With respect to practical aspects, a monitoring system must encompass both technical and theoretical considerations as well as meet the further restriction of ease of utilization. This is no easy accomplishment. The methods employed must be reliable, reproducible and easily carried out.

Olson (U.S.A.) stated practical monitoring has a difficult objective--to predict potential health threats. The best approach may be to examine the bathing beach as well as the effluent discharged to assess the maximum potential pollution which could reach the beach. She pointed out that the approach by Livingstone (South Africa) was admirable in its thoroughness, but required extensive laboratory expertise and analysis which are lacking in most monitoring laboratories in the United States.

Lastly, she queried if a simple E. *coli* index would have resulted in the same or different classifications of the bathing beaches studied.

Best (South Africa) asked Livingstone (South Africa) to comment on a recent newspaper report which implied cholera had been found in shellfish as well as along the beaches. Livingstone (South Africa) replied that shellfish have the ability to concentrate bacteria from water, rejecting most of the particulate matter. He further stated that shellfish which had been properly cooked posed no health threat. He said the source of these organisms was not the outfalls but was from the rivers and drainage ditches which contain large amounts of *Vibro cholerae*.

Shuval (Israel) queried Livingstone (South Africa) on what can be gained from a battery of tests rather than one test. He suggested an analysis of the data to determine whether this change would have resulted in any other outcome in the classification of the quality of the bathing beaches. Shuval (Israel) went on to state that schemes used in public health determinations must be understandable and easily carried out. The basis of monitoring is to establish a simple straightforward system which could use a statistical basis for a rapid test applicable to many areas where you can take into consideration daily variations over a bathing season. By using a highly complex scheme with many of the tests having a questioned validity, the purpose of the monitoring operation is defeated. Monitoring should be aimed at routine, relatively inexpensive tests which predict the state of quality. He referred to Cabelli's study which is the only one which exists today which indicated that *Enterococci* and E. *coli* correlated with disease. Primarily, rotavirus among children is the suspected causative agent.

Livingstone (South Africa) replied that the study was aimed in two directions. One clearly showed when pollution was from an outfall, E. *coli* or even *Shigella* or fecal segments containing *Taenia* could be found. However, in beaches affected by nonpoint sources, E. *coli* would not predominate. Also, when a sewage outfall is present, salinity is decreased.

Nupen (South Africa) commented on the degree of thought which had gone into the design of the evaluation system. She also commented that enterovirus monitoring was being carried out at these sites by her laboratory. Nupen (South Africa) asked what the correlation was between her coliphage tests and the present coliform system.

Livingstone (South Africa) replied that they were finding a trend between the coliphage and E. *coli*. He also said standard membrane filtration techniques were used to recover coliforms. His laboratory had selected MacConkeys agar which is not used by all countries.

Grabow (South Africa) asked if studies by Livingstone (South Africa) had shown that there were differences in the types of coliforms found in marine waters and how these factors might affect his water quality parameters. The author replied that his laboratory had examined a variety of coliforms as distinguished by the IMViC test. In addition, they examined *Staphlococci*, *Salmonella typhi*, *Pseudomonas* and *Proteus*. He stated that many of the common parasites found in stools were difficult to measure in seawater due to rapid distortion of the characteristics.

B. Paper No. 4: "Surface Dilution of Round Negative Buoyant Jets--A Comparison with Other Jets," by G. Noutsopoulos and J. Demetriou (Greece)

Sewage disposal in the marine environment usually occurs through a submarine pipe which often ends in a diffuser system. These systems depend on an effluent density lower than that of sea water to produce turbulence, mixing and dilution of the effluent at the surface. Orientation of the velocity vector at the discharge section, with respect to the gravitational field, plays a very important role in the flow pattern. Round vertically-upward discharged jets (positive buoyant jets) and round horizontally-discharged jets (horizontal buoyant jets) have been the most commonly studied. Surface dilution factors of a negative buoyant jet design was examined, and its effectiveness was compared with the other two designs. A negative jet design creates two flow boundaries: (1) internal: enclosing downward flow, and (2) external: enclosing upward flow. The internal flow is similar to the jet type while the external flow is similar to a plume flow pattern.

Experiments were conducted in a 1.15 m x 1.15 m x 1.40 m tank with glass vertical faces to observe flow patterns. An iron pipe of 2.1 cm ID was placed vertically in the tank to a designated depth. Tap water at a constant head entered the pipe and was released into a sea water solution with a density of 1.01 to 1.03g/cm^3.

The results indicated that the dilution distribution along the radial jet gave a continuous increase in dilution with distance from the jet axis. Surface dilution was larger for increasing radial distance from the jet axis and was found to be equal to that of a positive jet. Data presented by the authors indicated that the negative jet design would be better in very shallow waters. Dilution with the horizontal jet was found to be less than that of the positive jet and, therefore, was less than the negative jet design.

Negative buoyant jet design could be useful from an engineering standpoint when it is difficult to lay pipe along a bottom or in very shallow waters such as are found in the Mediterranean The same dilution as is achieved with more traditional designs can be achieved and thus the negative jet appears to have some useful advantages depending on circumstances.

The invited discusser stated that the approach of the experimental work was most innovative. He also pointed out that the amount of scatter which appeared in dilution data made it difficult to determine if there was a good relationship between the negative and positive jet design. Further, he stated that the authors should have placed confidence intervals around the regression lines to more accurately interpret the data. The discusser also indicated that the cost involved in erecting a negative jet would outweigh its usefulness under most circumstances. A discusser inquired as to the reason that the authors felt there was so much scatter obtained in the plume region. The authors responded that this was due to the very small values of mass concentrations obtained at the level of measurement.

C. Paper No. 7: "The Distribution and Significance of Toxic Metals in Sharks from the Natal Coast, South Africa," by R. J. Watling, H. R. Watling, R. C. Stanton, T. P. McClurg and E. M. Engelbrecht (South Africa)

The main thrust of this paper can be divided into two areas: use of sharks as a bioassay system for pollutants of the ocean and the distribution of metals in three types of sharks. The Mako shark (*Isurus oxyrhincus*), Dusky shark (*Carcharinus obscurus*) and Great White shark (*Carcharodon carcharias*) were selected for their differential feeding habits. The Mako shark is known to consume fast-swimming palaegic fish while the Dusky shark consumes pilchard and the Great White shark is known to consume dolphins and whales as well as pilchard. The value of such an assay system is in the generalization of the findings from a top carnivore in the food chain. The shark population may be able to delineate the general pollution status of the deep ocean as well as near-shore oceans.

The major findings of the study are summarized in the distribution of the metals in shark tissue. Sharks are unique in the fact that they rapidly lay down recently consumed products in their tissue because the kidney is inefficient in excretion. This is another reason why sharks are likely to retain the majority of pollutants taken in. The authors indicated this particular type of organism would be a good pollution indicator because of the rudimentary structure of the kidney. Most of the elements studied are deposited in the liver and muscle. There are variations in the amount of mercury and other metals which were laid down in various tissues of the shark. Mercury was laid down in the muscle and also the brain. The liver contained high concentrations of most metals including cobalt. The levels of cadmium were high in the liver of the Dusky shark. Mercury, copper, lead and zinc were able to enter the embryo of these viviparous organisms while cadmium was excluded. It was also found that with certain sharks, the Dusky shark for example, there was an exponential relationship between total length and concentration of mercury but that this exponential relationship did not exist between metal and total mass. It was the opinion of the authors that perhaps an asymtotic relationship would be reached in terms of mass. Mercury, the primary metal of study, was found to be in three forms: methylmercury, ethylmercury and a third unidentified form which was believed to be a phenolic form of mercury. The authors believe that if this latter type were indeed an aromatic mercurial compound that it would indicate the laying down of an unmetabolized pollutant in the tissue of the shark. This would mean that the organism was excellent at indicating pollution of this type. The authors concluded that sharks could be an excellent monitoring system for sea fisheries for such metals as copper, lead, zinc and mercury. They felt that the use of the indicator could be extended to certain other compounds such as polyaromatic hydrocarbons.

The comments of the official discusser, Massaro (U.S.A.), centered on sources of mercury pollution. He pointed out that approximately 10,000 tons of mercury are mined and distributed each year. Further, mercury is added to the atmosphere through the use of coal and oil as well as the smelting of sulfide ores and in the production of cement. However, he noted that 175,000 tons of mercury are released into the atmosphere via degassing processes in the world. Increases in the degassing rate through farming and other earth-moving practices may be substantial. Massaro (U.S.A.) noted the problem with the localized inputs of mercury and the possibility for poisoning. He cited one example in which the normal background level for fish is considered to be 0.2 mg/ℓ mercury (wet weight). Fish do not exhibit toxic effects up to and including 10 mg/ℓ mercury (wet weight). He noted that individuals who became ill from consuming fish in Minimata were consuming fish which contained approximately 50 mg/ℓ (wet weight). He also stated that it is not unusual to find fish in or from palaegic waters which contain 5-6 mg/ℓ mercury. Given these factors, he went on to state that our understanding of mercury is not complete at this point. For example, what occurs when other metals are also present in the fish? He pointed out that the toxicity of mercury is ameliorated by selenium. Selenium has been found in high concentrations in tuna. Does this mean that the individual who consumes tuna with high concentrations of both mercury and selenium is at less risk than a person consuming a fish with high concentrations of mercury alone?

The author responded to the questions of Massaro (U.S.A.) at three levels. The first two of these concerned the question of how to define an adequate standard for the intake of metals by the population at large. He pointed to the fact that how to obtain samples from a fishing boat is an extremely difficult question which has not yet been properly addressed. He gave the example of Italy which requires 10 fish to be examined from a boat containing 1,000 fish, 20 fish from a boat containing 10,000 and 25 fish from a boat containing 100,000 fish. It is obvious that the possibility of sampling error utilizing such techniques is great. However, the accuracy necessary perhaps to produce a statistically meaningful sample may be cost prohibitive. However, the point taken by Watling (South Africa) should not be ignored but should be aggressively addressed. It must be possible, given our scientific knowledge and background, to develop a method of sampling which provides adequate information as to the metal or pollutant concentration in the fish in a cost effective manner.

The next question concerned how much of a metal should a given community be allowed to ingest. Watling (South Africa) rejected the idea of a fixed number but suggested the use of a sliding scale that would be dependent upon the type of fish to be consumed and the type of community. By this latter statement, Watling (South Africa) was referring to the dietary habits of the community. This is an interesting concept which has not been explored to any great degree by regulatory agencies. The lack of interest in this type of approach is most likely due to the difficulty in trying to establish baselines for different types of communities and the complication of trying to discern the eating habits of an area. However, this does not negate the merit of the approach and perhaps we should begin to look at alternatives that are not based on absolute numbers.

Massaro (U.S.A.) pointed out that it was unfortunate that the authors did not report on selenium in sharks. Watling (South Africa) responded that the selenium analysis technique had not been perfected in their laboratory at the time the investigation was undertaken. He further pointed out that, in an international round robin, their laboratory was obtaining values 20 times higher than reported for the standard sample. He attributed this to the use of a closed sample technique which he believed was recovering higher amounts of selenium than are found in ordinary analytical techniques. He stated that his laboratory would soon be able to analyze for selenium, arsenic and antimony. The question of analyses for both selenium and arsenic is one of difficulty. No matter what the medium being analyzed, it still presents analytical problems. Until it is possible to obtain reliable measurements of selenium in various biological tissues, the question of its use on a wide-scale basis is difficult.

Chapman (South Africa) inquired about the use of the geometric mean in statistical analyses. He further asked whether the use of the geometric mean meant that there was a high variation for the metals encountered in the sample tissues, as was reported in the figures for mercury.

Watling (South Africa) commented on background variations and said that their values for their shark population studies were near background levels. He then referred to another report which had investigated sharks captured on the west coast of South Africa whereas their study was done on the east coast. West coast values were an order of magnitude lower. He hypothesized that the reason why levels in shark tissues from the east coast may have been higher were due to the more polluted nature of the east coast and perhaps to the sharks having taken prey with higher levels of metal. He reiterated the need for monitoring which would give information on the fate of pollutants in deep ocean species at the top of the food chain.

Olson (U.S.A.) asked whether the authors were able to determine if the sharks had fed in a localized area or whether their intake had spanned a very wide range of the ocean. She further queried whether or not this targeted indicator organism could be used for other organic pollutants.

Watling (South Africa) responded that it was difficult to determine the actual feeding patterns of sharks and that tagging was being carried out in order to increase the understanding of shark migrations through the oceans. A larger data base was needed to interpret the findings to particular sites. He also stated that sharks appear to be excellent for monitoring such compounds as PCB, DDE, DDT, Dieldrin and Camphloclor. These compounds had been found in high concentrations in both shark liver and muscle. He said that their laboratory had plans to expand their analyses to cover other aromatic hydrocarbons.

In conclusion, it would appear that sharks are an interesting organism to view in terms of monitoring. There appear to be, as with any monitoring system, some difficulties yet to be worked out such as the migratory patterns and exact diets of these fish as related to potential pollution hazards. Even given these drawbacks, the use of sharks for pollution monitoring seems at this point to be an excellent potential indicator of the pollution status of the deep oceans.

D. Paper No. 10: "Baseline Studies and Continuous Monitoring for a Shallow Tropical Bay Receiving Nickel Refinery Effluent," by J. E. Carey, M. A. Pettit, W. S. Rooney, and T. L. Judell (Australia)

Judell (Australia) presented the paper on predischarge baseline studies and long-term post-discharge surveillance program undertaken to monitor the effect of nickel refinery effluent on coastal waters on Halifax Bay, Queensland, Australia. The plant producing the effluent was an ammonia leaching refinery. There are only two of these refineries in the world. In order to determine the toxicants which should be investigated, short-term toxicity studies were conducted. These tests were made utilizing two types of commercial fish, Golden-Lined Whiting, *Sillago analis*, and Northern Whiting, *S. sihama*. The tests demonstrated the amount of ammonium sulfate, free ammonia, nickel and cobalt which could be released in the effluent without overt toxic effects. Longer term studies involved determining water movement in Halifax Bay. The findings from this part of the study showed that the Great Barrier Reef, located 30-40 km from the receiving water in Halifax Bay, was not affected. The discharge was released through an outfall 20-30 km in length equipped with a horizontal diffuser. These findings also showed that flows from creeks from the immediate vicinity had a dramatic effect on water quality. Differences in water quality during wet and dry seasons of the year were noted. Sediment studies were also carried out to determine if nitrogen affected activity within sediments. Sediment samples were analyzed for grain size, Eh-pH measurement and chemical analyses. Seawater was also characterized for sodium, potassium, calcium, and magnesium concentrations and a number of trace elements including nickel, lead and cadmium. Further, pH, chlorinity, ammonia-nitrogen, nitrate-nitrogen, total phosphate-phosphorus, turbidity, temperature, visibility, BOD, nickel and cobalt concentrations were measured at quarterly intervals.

Chlorophyll-*a* concentrations were monitored on a monthly basis as an indicator of phytoplankton standing crop. A decrease in chlorinity and an increase in all nutrients were evident after the beginning of the wet season (January - March) as a result of land runoff. Phytoplankton growth was also affected during the wet season. Natural phytoplankton blooms of the blue-green alga, *Trichodesmium* species, were found to occur with rises in temperature and influx of nutrients which led to fish kills. The author emphasized that the complexity of the marine ecosystems suggested that many years of *in situ* monitoring of biological responses to effluents are needed before modeling for predictive purposes will be possible.

Benthic vertebrates present on the sea floor were also used as models because they may be indicators of changes in the environmental conditions. Results showed that in intertidal zones, with its constantly changing microenvironments, relationships between substrate type and faunal communities were the most pronounced. Bivalves were the most abundant group of organisms in the intertidal habitat. In soft substrates, polychete worms and crustaceans predominated.

Shannon-Weaver indices were computed in order to determine diversities. The results indicated that no differences could be discerned from inputs of effluent. No effect was noted on commercial fishing in the bay.

The authors pointed out that in long-term monitoring, consistency and continuity of operators and their supervision of sampling sites must be considered. They emphasized that standardization of methods, both sampling and analytical, was necessary in order to produce meaningful results.

The authors also pointed out the importance of the stability-diversity hypothesis which has been used in recent years as a basis for water-quality assessment. The purpose of the index is to show that in stressed environments,less diverse communities are found, while in stable environments, the diversity of the community or the number of species encountered increases. However, in practice there appears to be no simple relationship between diversity and stability. The authors pointed out that diversity may vary for reasons other than environmental stress, such as species interactions, climatic variability and greater spatial heterogeneity of the habitat.

Clark (United Kingdom) stressed two main points in his formal discussion. The first of these was the general importance and difficulty in carrying out a comprehensive monitoring program. No matter how good the study, problems will still exist because there are no methods yet developed which measure small changes in the community. Measurements of diversity are not always reliable in describing why changes are occurring, including the indices used by the authors and exemplified by the disagreement between the Shannon-Weaver index and the Gray and Mirza log-normal diversity index. He further stated that the time of year that sampling is carried out can be extremely important. One would wish to pick a time of year when natural perturbations were at a minimum. The two examples of high mortality, independent of environmental inputs (after spawning and the entry of new recruits into a community which usually die), cause erratic changes in the diversity index for a short period of time. In England, the optimum time of the year for such a diversity study is during the autumn when natural perturbations and fluctuations are at a minimum.

Clark (United Kingdom) emphasized the need for more than mechanical methods in order to understand changes in the ecosystem. He mentioned the extreme difficulty in this pursuit given our current technology in ecosystem study, even in areas where the species are well defined and where the habits of these species are known and the ecosystem function delineated. In areas where little is known about biology, one must rely on measurements of change such as diversity indices.

The second point of the discussion focused on the length of a monitoring program. Clark (United Kingdom) indicated that large impacts from an effluent are obvious and changes can be determined in a very short period of time. However, if changes are difficult to detect, then it becomes virtually impossible to evaluate or to measure toxic effects. One can conclude from this either that no toxic effects are occurring in the environment or that the methods used are not sensitive enough to delineate a toxic occurrence. He concluded by stating that until the structure, energetics, and functions of an ecosystem under study are understood, it will be nearly impossible to monitor subtle changes due to effluent input.

The reply by Judell (Australia) centered on the length of the monitoring period. He stated that the prolonged monitoring of an area produced management benefits as well as scientific benefits and, if routine monitoring could be carried out economically, then all would benefit. The information gathered by the management could be disseminated to the government and aid the company and the government arriving at judicious standards and monitoring programs.

Rosemond (Australia) commented at some length on the initiation of the study. At the time the study was initiated, he was director of the Water Quality Council which was directed by the Queensland government to establish the monitoring program with the consultants. His comments centered on several points. Although an industrial process has been used in another part of the world, he emphasized the importance of understanding how that process affects a specific environment. Further, findings from one environment are not always translatable to another. Secondly, he emphasized the importance of decisions having to be made in a political atmosphere. During these times it was his opinion that decisions must be made quickly and based on a minimum amount of information. It appears from the types of decisions made in this arena that it is possible to achieve results which are satisfactory to all and which protect the environment. This third point was that monitoring should be based on trends rather than on setting a single number standard. He concluded that although there was no difficulty nor noticeable problems being experienced with discharges of this effluent into Halifax Bay, fish kills occurred when effluents spilled into nearby wetlands. Pointing out that judicious and vigilant observations are always site specific, he believed that long-term monitoring is needed to distinguish between slight perturbations in the environment caused by an effluent and those which occur naturally.

Froneman (South Africa) questioned the effects of free ammonia. He again reiterated the facts pointed out in the paper that free ammonia is toxic and that toxicity is pH dependent. He further stated that his data showed fish kills could be caused by small increases in temperature at a pH of 8 due to ammonia. Judell (Australia) replied that these factors had been taken into consideration but *in situ*, no differences in toxicity could be noted even during the warmer months. He also stated that the complexity of the *in situ* environment vs the laboratory environment again causes one to be cautious when findings are translated from one set of conditions to another.

Walmsley (South Africa) asked if any evidence of bioaccumulation of either cobalt or nickel was observed in the benthic fauna or fish. He stated there was no difficulty with discharge of these elements into the bay if bioaccumulation of these substances were absent. Judell (Australia) then referred to work by the Southern California Institute which studied metal uptake around marine outfalls into various types of fauna. These findings have shown that organisms which are bottom feeders tend to be the most at risk, and, with many of the metals studied, there is no evidence of food-chain accumulation.

Beckman (South Africa) wanted to know the value of doing baseline studies in an area which had been discharging industrial and domestic waste for over one hundred years. Judell (Australia) did not comment on this directly. However, no matter what the current situation is, it is important to assess the before and after effects. If baseline studies are conducted, then any change for the good or for the worse can be ascertained.

Hughes (United Kingdom) stated that a better understanding of the fate of metals in the ecosystem itself was necessary. As examples, he utilized studies of cadmium and mercury uptake in the muscles of flounder in the Thames River and the fate of phosphorous as measured in the liver of certain Thames River fish.

Final comments by Judell (Australia) centered on whether such studies should be conducted and the benefit to the public. The conclusions which can be drawn from this work done in Australia can be broadened to any country of the world. By doing careful monitoring before the initiation of discharge of certain types of effluents into the environment, and by following the fate of that ecosystem after the discharge into the environment, it is possible to ensure that the public interests as well as economic interests are protected. Industry is provided with the maximum amount of information concerning its effluent discharge from such studies which may benefit management practices. Technologists are employed in policy-making decisions from the beginning as opposed to being utilized at the end to try to solve some disastrous problem which has arisen.

Four main summary points can be reiterated. (1) Changes in the environment are difficult to measure; new methods are needed; (2) Better understandings of ecosystems are necessary to elucidate perturbation problems of natural or man-made sources when inputs do not have a catastrophic effect; (3) Monitoring programs can be beneficial to industry and government as well as to the public by contributing knowledge which has generalized benefits; and (4) Better policy decisions are derived from the interaction of these three sectors if decision making begins early in the process.

E. Paper No. 13: "Influence of Discharges from Storage Reservoirs on Tastes and Odours Appearing in the Seine and Marne Rivers," by M. Rizet and J. Mouchet (France)

Taste and odor problems in the Seine and Marne Rivers which serve as a major drinking water source for the city of Paris had occurred intermittently for several years. These problems became acute during a drought in 1976. An interagency agreement among all the authorities in the basin was entered into in order to remedy this problem. The sources of noxious compounds were found to be produced by different nuisance organisms in the two rivers. Therefore, a study was conducted to compare the physico-chemical and biological characteristics of the two river system.

Sampling locations were designed to sample water in each system above the reservoir, in the reservoir, at the discharge point from the reservoir and downstream near the city. The study included the identification of microorganisms which could give rise to uncertain tastes (algae and actinomycetes) as well as identification of other organisms which might contribute to taste and odor problems. The presence of geosmine and methylisoborneol and other biological and physico-chemical parameters of the water systems were determined.

During the year from July to November, the Seine Dam discharges 88-90% of its stored water. During the floods in December through February, some water is also discharged. In the Seine upstream from the dam, the taste thresholds did fluctuate depending on the density of suspended solids. In the reservoir, the intensity of the taste is at its maximum in the summer period with the proliferation of algae. However, it was not possible to correlate this with geosmine or 2-methylisoborneol.

The level of suspended solids is systematically higher downstream as compared to upstream of the weir. Sediment deposition into the stream is dependent on the discharge point in the reservoir. Some of the sediment input is attenuated in the canal leaving the reservoir. The discharge of silt can also add algae such as *Oscillatoria agardhii.* This bluegreen alga cannot be isolated downstream when the dam is not releasing water. *Actinomycetes* do not appear clearly, except in the suspended solids during flooding.

The Marne Reservoir which is more recent in construction provides storage of more than 350 x 10^6 m^3 of water. The management of this reservoir is different in that water is discharged from July through December. Beyond this period discharges are negligible compared with the flow of the river. The reservoir reduced turbidity, except near the end of the discharge season when the water level in the reservoir is quite low. Four peaks in geosmine were measured in the upstream part of the Marne. They had no apparent relationship either with the suspended solids or with the *Actinomycetes*. *Actinomycetes* and suspended solids during the flooding periods were closely associated. But no relationship between these organisms and the actual taste of the water could be demonstrated. However, in the reservoir the growth of *Oscillatoria* was noticed in October which did coincide with a high concentration of methylisoborneol. This compound was not found downstream from the weir.

Comparing the two rivers at the level of the reservoirs, *Oscillatoria* reproduce in the Seine whereas in the Marne River they disappear. The algae do seem to contribute to taste. First, the reservoir is shallow which encourages penetration of light and stimulates growth. Silt or mud transported from the reservoir accumulates on the bottom of the stream or river and algae brought from the reservoir either die, as in the Marne, or flourish, as in the Seine. Rizet (France) concluded the problem of the river water quality from the point of view of preparing drinking water had not always taken into account downstream pollution sources from local sewage discharges and barrages (dams) on the river. Quality downstream from the reservoirs was also a decisive factor in the development of undesirable tastes as well as conditions which promoted the growth of these nuisances.

Gehr (Canada), the official discusser, stated that the authors attempted to explain the reasons for the taste and odors occurring in the Seine and Marne Rivers as a result of a drought and a subsequent flood which occurred about five years ago. They have obviously gone to considerable trouble to measure the water quality in terms of a number of chemical and biologic factors and have tried to relate the occurrence of these taste parameters to the influence of the reservoirs which separate the upstream and the downstream portions of the two rivers which supply water to the city of Paris. Gehr (Canada) asked about the methods used to quantify the tastes. Such a controversial parameter as taste should have a reference so that comparison with other work can be made. The authors make frequent reference to summer and winter and other seasonal terms which are rather vague, especially to those in the southern hemisphere.

Gehr (Canada) stated that, although the effects were clearly a result of some organic pollution, the authors present no data on BOD, COD, TOC and other organic parameters. Temperature data would be an important factor to be included in such a report. Gehr (Canada) emphasized that they should have indicated when the reservoir was reopened after its closing on November 10, 1976, because of its relevance to their conclusions. Gehr (Canada) then made comments with regard to the agreement between the data presented and the text. He pointed out that the authors found an association between algae and blue-green algae occurrence and taste units upstream and downstream of the dam. He further stated that the authors were incorrect in their statement that suspended solids were always higher at Villacerf than upstream of the dam.

Gehr (Canada) only discussed the analysis of taste problems for the Seine River. He concluded that although changes had occurred in the physico-chemical and biological parameters of the water during its storage in the reservoir, these changes could not be related to changes in taste of the water. This was recognized by the inability to correlate geosmine and methylisoborneol with the occurrence of algae. Importantly, if only blue-green algae are the cause of the taste problems, then correlations should only be found for the geosmine, but if Actinomyces and blue-green algae were responsible, then both compounds would be present. The discusser concluded by stating that more concrete data were needed to definitely show that the reservoir was the source of organisms responsible for the taste problems.

Rizet (France) replied that the method used to quantify tastes were made by individual tasters and threshold levels established from these experiments. She also stated that COD and TOC were determined although the results were not presented. Rizet (France) commented that it was difficult to relate Actinomyces to taste problems because certain species produce compounds influencing taste while others do not. Therefore, no simple quantification of this group of organisms can be used to correlate with taste levels. In regard to the text not corresponding with the information presented in certain figures, Rizet (France) acknowledged errors in certain figures.

Rogers (South Africa) queried the authors as to whether depth stratification in the reservoirs was a factor contributing to taste problems and what treatment could be used to alleviate taste problems. Rizet (France) replied that depth stratification was not the main problem especially in the Seine Reservoir which has a high degree of insiltation in certain locations. As to the removal of tastes, activated carbon and ozonation have proven useful, but these processes are costly.

IV. CRITIQUE OF SESSION

Paper No. 1 clearly pointed out differences in philosophy on how to develop a monitoring scheme to predict quality of bathing beaches. Although Livingstone's (South Africa) presentation showed that quality was improved with use of treatment and an ocean outfall, the discussion focused on the rationale of the monitoring scheme. It was clear that the audience held two main points of view: the system must be practical and relate to health or the system must be able to demonstrate a change in quality, regardless of its relation to health considerations. Both have validity, the former in that health protection is the major aim and the latter in that a positive or negative outcome on microbial quality can be demonstrated.

The concept of how to develop a monitoring scheme would create debate no matter what the composition of the audience or the quality of the methods. As yet, little common ground exists for a consensus among researchers in different countries.

An interesting and novel concept concerning the development of a pollution monitoring system for the deep oceans was presented in Paper No. 7. It is difficult to ascertain the full potential of the system at this stage, because it is in the early phases of development. Therefore, several problems remain to be solved. The migration and feeding patterns of the sharks under study must be fully delineated if the source of the pollutant is to be determined. The real promise of the method is the inefficiency of the shark kidney which allows the rapid deposition of the pollutant into the tissue. This appears to provide an excellent mechanism to trace the migration of pollutants in the food chain. If pollutants are laid down in an unaltered state, and if migration patterns as well as feeding patterns are established, it may be possible to track the movement of the pollutant through the food chain. Further, the movement of the pollutant as it travels within a specific segment of the food chain could also be delineated.

Paper No. 10 was excellent in demonstrating the benefits of a well-designed, before-and-after monitoring investigation. It could be seen from the discussion that the information being obtained extended byeond the context of the study by pointing out significant difficulties with designing and carrying out monitoring investigations aimed at the impact of a particular pollutant on an aquatic environment. The discussers raised valid and important points on the utility of species diversity indices as a measure, when they can be useful, when they are inappropriate and under what conditions they can soley be relied upon. What all the discussers and author agreed upon in principle was the need for more information on the ecology of aquatic habitats. It is difficult to determine impacts to recommend satisfactory regulations to protect that environment.

The research presented in Paper No. 13 represented a cooperative venture among several scientific groups. The information contained in the article, therefore, excluded certain data critical to the overall conclusions drawn. A more complete understanding of the study could be obtained from the final report submitted to the basin interagency group. Yet, with any study of this type, two factors should be kept in mind. First, various nations have different emphases in approach, and second, this directional focus is likely to influence the nature of the data obtained and the uses to which those data can be applied.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

With regard to the significance of Paper No. 1, most recent work relating health significance to pathogens in marine bathing waters has occurred in the United States. The work done by Cabelli and associates demonstrated an association between E. *coli* and illness among children. More recent studies by Fattal in Israel showed that both E. *coli* and enterococci correlated with virus occurrence in marine bathing waters associated with raw sewage inputs.

In the United States, raw sewage discharges are infrequent compared to such discharges in many other countries in the world. However, cholera is again becoming a disease of note in the United States, not because of the large numbers of the population affected, but more so because of the relationship to consumption of shellfish. The occurrence of pathogens, especially viral agents (i.e., hepatitis A), in waste discharged near shellfish growing grounds must be viewed as a critical issue in the United States. Adequacy of disinfection in light of particulate association by pathogens, clumped configurations and injury of the organisms has not been resolved to any satisfactory extent.

Illness from exposure to bathing waters appears more complex but the Cabelli work indicated a viral agent may be responsible for disease in children, the main affected population. Unfortunately, at the time of the Cabelli studies viral techniques had not progressed to present-day sophistication and therefore, direct proof of viral-caused illness was not possible at the time.

At this stage, it is difficult to determine the relative usefulness of the technique presented by Watling et al. (South Africa) in Paper No. 7 to the United States. The concept of monitoring the oceans with a biological organism is interesting. The return from investing in such research would have to be viewed at this time as risky. However, if national needs are such that it is important to track the fate of a particular pollutant in the oceans from its origin to its final site of deposition, then this may be an excellent tool to pursue vigorously. Certainly, it appears to have applicability far beyond that of metals. Sharks could also be used to monitor the presence of a number of highly sensitive organic pollutants such as PCBs, DDT, DDE, and aromatic hydrocarbons.

Any program which utilizes before-and-after monitoring when introducing a pollutant into an environment is to be commended (Paper No. 10). As pointed out by the authors and the discussants, it resulted in better policy decisions and improved relationships among industry, the public and government. The regulations arrived at were satisfactory to all, because all had participated to some degree in the process developing those regulations. Attitudes of countries vary greatly on whether to adopt such extensive monitoring strategies. But, as was pointed out in the discussion, results from studies should not be extrapolated too widely. This appears particularly true in the case of an environmental pollutant. Each environmental location has its own sensitivities. One message from several nations which was clearly evident from discussions throughout the conference is the need to support basic ecological studies through such programs as the National Science Foundation. Without these baseline studies or the development of such tests as diversity indices, there would be little hope of measuring effects of pollutants short of those producing lethal outcomes. Needs are clearly directed toward the development or the application of testing methods which distinguish the subtle effects a pollutant may have on an environment. The United States would greatly benefit from the information derived from such studies as would all the countries in the developed world and even more those developing nations which would like to avoid costly environmental mistakes.

Taste and odor problems, as presented in Paper No. 13, continue to be a major concern of water agencies throughout the world. In the United States, the approach has been to assess the presence of the two main taste-producing compounds: geosmine and methylisoborneol. Even with our level of sophistication in the measurement of these problem compounds, our ability to apply satisfactory corrective measures lag well behind. There is a continuing need for research to study factors which influence the growth of organisms capable of producting taste problems. Once these parameters are understood, it will be more likely that an effective management strategy will be attainable. This investigation (Paper No. 13) has taken steps in the right direction. However, without reviewing the full report, it is impossible to say that this study led us any closer to information on how to remove the causative agents of taste problems from our reservoirs. Removal at this point in the time appears more feasible than treatment of affected water due to cost factors.

2

I. SESSION

A. Day: Tuesday, March 30, 1982
Hall: A
Time: 8:30 a.m. to 12:05 p.m.

B. Theme of Session: Water Quality Management

II. REVIEWER

A. Name: Edward J. Massaro

B. Position and Affiliation: Director, Center of Air
Environment Studies and
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The Pennsylvania State
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III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 16: "New Methods for Analyzing Water Pollutants," by L. H. Keith, R. C. Hall, R. C. Hanisch, R. G. Landolt, and J. E. Henderson, (U.S.A.)

This paper discussed: (i) a new gas chromatograph (GC) detector; (ii) a method of multi-dimensional gas chromatographic analysis, and (iii) a computer-controlled GC used for the analysis.

The new detector is a thermally-modulated electron capture detector. It consists of two electron-capture detectors in series with a catalytic pyrolysis unit. A compound passes through the first detector into the pyrolysis unit where catalytic decomposition occurs. Then, one of three things can happen: the emerging peak either can be the same size as it was in the first detector (in which there was no decomposition) or it can be smaller or larger than it was in the first detector. This type of information can be used like a retention time or a melting point. Thus, under a given set of conditions, the physical property (i.e., the ratio of the two peaks) is a constant. This can increase the level of identification because a retention time as well as a ratio of the peak areas is obtained. By choosing the appropriate conditions, the peaks emerging from the pyrolysis unit can be made either larger or smaller than the peaks detected by the first detector and analytical selectivity can be achieved without going through the process of fractionating interfering compounds or classes of compounds from one another. This, in effect, is accomplished by the detector.

Examples of the advantages of the method were discussed such as: (i) the analysis of pesticides in the presence of PCBs in the absence of column chromatographic separation and (ii) the analysis of dihaloacetylnitriles in the presence of trihalomethanes. The dihaloacetylnitriles are a new class of compounds that are produced by chlorination of drinking water. They occur in many water supplies simultaneously with trihalomethanes. The dihalo compounds cannot be detected by the standard methods used for the analysis of trihalomethanes because they are destroyed.

Two-dimensional gas chromatography is a simple concept: the sample is chromatographed on one column and the compounds (peaks) emerging pass through a valve into an electron capture detector. From there, they pass into a second valve from which they can be either vented or trapped. After the first column run is completed, the trapped compounds are thermally desorbed on the head of a second column, the properties of which are different from those of the first column, and a second set of retention times are obtained. Using the two retention times, the confidence level of identification is increased significantly. This technique is called post-detector peak recycling or PDPR two-dimensional gas chromatography.

The utility of this technique was illustrated in a study in which haloacetylnitriles and trihalomethanes of drinking water were analyzed using samples spiked with standards. Small peaks that were not detectable on the first column because they eluted with the standards were detected on the second column. It is to be expected that the concentrations (i.e., integrated peak area) from both columns would be the same and, indeed, they were very close. However, there were a few exceptions. With dibromochloromethane, the relative concentration was 50 ppb on the first column but only 41 ppb on the second column. The reason for this is that there was an impurity under the peak in the first column. On the second column, the impurity was separated out. Thus, the true concentration probably was 41 ppb instead of 50 ppb.

It is, of course, not essential to have a computer-controlled gas chromatography to do two-dimensional gas chromatography. However, it is helpful because of the rapid switching needed to collect the peaks of a complex mixture. The design of the chromatographs described is somewhat different from that which others have used. The major difference is that a hot-air convection oven is not used. Instead, a hollow aluminum mandrel is used which can be heated or cooled very rapidly. Packed columns are wrapped around the outside of this mandrel. A capillary column can be placed inside of the mandrel. This type of system lends itself rapidly to mobile vans.

Van Rensburg (South Africa) congratulated Keith (U.S.A.) on the original thinking which went into the design of the instrument. The discusser asked to what extent that mention was made that the instrument had capillary column capabilities but, in the examples discussed, only conventional columns with approximately 1000 effective plates had been used. He asked for clarification of the advantages that the instrumentation described would have over modern, high-quality fused-silica columns which may have approximately 60,000 effective plates and the parallel dual detection system presented. Van Rensburg (South Africa) felt that in a dual detection system like the one described, chances were very good that a certain amount of resolution would be lost during the passage of the sample through the first detector, the oven and then the second detector. He suggested comparison of the system described with one manufactured by another company which uses capillary columns. Van Rensburg (South Africa) closed with a comment on the technique used to extract the nitriles. He mentioned that they were having a problem with pentane as a solvent when automated water sampling techniques were used. The problem was that pentane tended to form air pockets in the syringe needle.

Keith (U.S.A.) replied that their instrument could be used both for research and routine applications. They have used it in the research mode; however, it can be set up for routine analyses. In fact, using an auto injector, it should be possible to routinely analyze many samples. The software program should not be difficult to write, the instrument is not difficult to operate and can be operated by a trained technician. The cost of the instrument is approximately $60,000 ($20,000 for the computer and $20,000 for each of two gas chromatographs) which is comparable to other instruments on the market containing a comparable data system and two gas chromatographs.

The instrument has not yet been used with capillary columns. With respect to loss of resolution with the thermally-modulated electron capture detector; they have seen only a slight loss of resolution in the second detector following passage through the catalytic decomposition unit. This may be due to the fact that the detector is a prototype detector and has not optimized with respect to dead volume which would prevent loss of resolution.

Keith (U.S.A.) mentioned that a parallel system of detectors could be used with their instrument. However, sensitivity would be cut in half because only one half of the sample would be sent to each detector. If loss of resolution is not significant, it is preferable to use the detectors in series because of the higher sensitivity obtained. Keith (U.S.A.) indicated that they have not had any problems with pentane extractions. However, other solvents are available and in use.

Saunders (South Africa) requested information on the size range of the molecules that Keith (U.S.A.) has been able to analyze with his instrument. Keith (U.S.A.) replied that they have concentrated on smaller molecules and have not analyzed large molecules.

Van Rensburg (South Africa) commented that the important thing is use of efficient columns such as capillary columns with about 60,000 effective plates. With such columns peaks would be sharp and a parallel system would be highly efficient. He added also that the electron capture detection system has its limitations as to the type of compounds to which it is sensitive and asked whether other types of detection systems could be used with the instrument described.

Keith (U.S.A.) replied that the point made about the capillary columns was a good one. With respect to other detectors, if you had two columns in parallel, you could use other types of detectors. In fact, at a chlorination conference held in October (1981) in the United States, such a system was discussed in which a flame ionization detector and a flame photometric detector were utilized to analyze for volatile components in drinking water. He mentioned also that some people have problems with injection into a capillary column and that he has had problems in training technicians to use capillary columns. Once this is overcome, then capillary column chromatography always is superior to packed column chromatography.

In conclusion, Keith (U.S.A.) commented that there were many things that have not yet been done with their analytical system. For example, combining the new detector with two-dimensional gas chromatography would allow identification of compounds by peak ratios and two retention times; greatly increasing the confidence level of the identification. Interfacing two-dimensional gas chromatography and mass spectrometry would allow for the identification of unknowns, which cannot be done by single-dimensional GC-mass spectrometry. For example, there are times when a compound that has been identified by gas chromatography using a Hall detector or an electron capture detector cannot be identified by mass spectrometry because the peak cannot be found. It may be buried, for example, under larger peaks. This, in fact, is a common situation in environmental analyses--not being able to identify small compounds which may be the toxic compounds of interest because they are buried under other compounds. Using two-dimensional gas chromatography-mass spectrometry (GC-GC-MS), the peak (or peaks) of interest could be trapped after chromatography on the first column and rechromatographed on the second column to move the compound of interest out from under the interfering compound(s). Another situation which often prevails is that in which a sufficient amount of the compound of interest cannot be placed into the MS ionization source because of the presence of large amount of extraneous compounds. This happens particularly with capillary columns. Only so much can be injected into a capillary column. Using two-dimensional gas chromatography, multiple injections could be made and the compound or compounds of interest could be trapped while the extraneous compounds are vented. When a sufficient concentration of the compound(s) of interest was built up, it (they) would be thermally desorbed onto the second column and rechromatographed and enough material would be available to obtain a good mass spectrum.

B. Paper No. 18: "Simultaneous *in situ* Determination of Dissolved Gases by Gas Chromatography: II Oxygen and Nitrogen in Activated Sludge Process Streams," by T. Bilstad and E. N. Lightfoot (Norway, U.S.A.)

This presentation dealt with the measurement of dissolved gases in water. It is well known that water supersaturated with dissolved gases can have deleterious effects on fish and other aquatic species. Due to its chemical properties and physiological effects, nitrogen gas (N_2) is of special concern. Nitrogen is only half as soluble in water as oxygen, but air contains nearly four times as much nitrogen as oxygen (i.e., the partial pressure is four times as high). Therefore, at equilibrium, water contains nearly twice as much dissolved nitrogen as oxygen on a mass basis (i.e., at 20°C there are 16 mg/ℓ of dissolved nitrogen and approximately 9 mg/ℓ of oxygen). Thus, in certain parts of the world such as Norway, the northwestern United States and other places with waterfalls, dissolved nitrogen gas is an important water quality parameter. Dissolved oxygen is readily measured either chemically by titration or by specific electrodes and both methods are cited in the standards. However, no standard exists for dissolved nitrogen. Neither is there a standard measurement technique. Therefore, how can dissolved N_2 water quality standards be made, complied with and enforced in the absence of a standard measuring technique?

Chromatography (GC) can provide separation of several gases. However, the problem is the accuracy and precision of transport of dissolved gases to the GC for analysis. This may be accomplished employing a membrane diffusion cell which was described. It consisted of a nonselective silastic membrane in tubular form (0.5 mm inside diameter; 0.25 mm wall thickness) attached to two stainless-steel capillary tubes which connected the membrane to the gas chromatograph. The membrane is immersed in the water sample and the dissolved gases diffuse from the sample through the membrane and are swept into the GC by the carrier gas. The gases were separated on a column packed with molecular sieve 5A. In effect, the plug of stationary gas accumulated inside the hollow membrane is transported to the GC column by directing the helium purge gas through the capillary tubes connecting the membrane to the GC. With the apparatus described, the output signals from the dual thermistor detector of the GC were recorded on the chromatogram and the peak areas integrated. The precision of the technique apparently is high both for dissolved O_2 and N_2 and, over a wide range of concentrations, there is linearity of response. In addition, there is no appreciable interference between the two gases. It is to be noted that temperature is very important in membrane diffusion and all studies were made at a constant water temperature. For calibration purposes, dissolved oxygen was calibrated by Winkler titration and the van Slyke method and nitrogen by the van Slyke method, the only technique available for measuring dissolved nitrogen.

A number of measurements of dissolved O_2 and N_2 in activated sludge process streams were made with the membrane. There was no doubt about the linearity of the response both for O_2 and N_2. Also, there appeared to be no appreciable interference between the two gases. Another important feature was the stability of the probe in the heavy suspensions of activated sludge. One membrane was used throughout two months of work on the sludge streams and linearity of response was maintained.

In conclusion, the membrane/gas chromatographic technique described offers a promising method for dissolved nitrogen measurements. This system appears accurate to within a standard deviation of 0.5% both for nitrogen and oxygen.

Van Rossum (South Africa) commented that once you have a suitable membrane technique, you can start considering alternative detection systems such as the mass spectrometer. Small quadrapole-type mass spectrometers (small enough to be carried about in a suitcase) with a mass range of up to 80 are now available and would allow detection of any of a wide variety of substances. Van Rossum asked Bilstad to comment on the potential problem of membrane fouling.

Bilstad (Norway) replied that an alternative to the GC for measuring dissolved gases in the field is the saturometer: an instrument that measures the total dissolved gas content of water and can be used at great depths. Bilstad (Norway) indicated they have been satisfied with the gas chromatograph and the next step for them would be to use other columns in the gas chromatograph for the quantification of other dissolved gases in addition to nitrogen/oxygen. For example, it should be possible to measure NH_3, H_2S, and CH_4. He stated also that membrane fouling has not been a problem in their studies.

Roberts (South Africa) commented that those who have worked with nitrogen mass balances in nitrification/denitrification activated sludge plants have been calculating mass balances with no regard for dissolved N_2 and have been happy with the balances obtained. He asked Bilstad (Norway) to comment on the kind of variations found in dissolved nitrogen levels in different parts of reactors in activated sludge plants.

Bilstad (Norway) replied that when ammonia is oxidized and then denitrified to N_2, you would expect to get dissolved nitrogen in the last stage of the process. He noted that people have had problems with nitrogen balances in plants that nitrify (and therefore, also denitrify) in the settling tanks. He stated that although you may obtain accurate data on organic nitrogen, ammonia, and nitrate concentrations, without information on dissolved N_2 levels (if they exist), no balance is attainable. The plant in which Bilstad (Norway) measured dissolved nitrogen was an activated sludge plant without denitrification and little nitrification. The N_2 saturation data he obtained was of the order of 118%, i.e., supersaturated.

Gold (South Africa) asked: (i) why a period of two minutes of exposure of the diffusion cell to the test sample prior to measurement was selected and (ii) what was the effect either of shorter or longer periods of exposure?

Bilstad (Norway) replied two minutes was the minimum time required to obtain sufficient gas diffusion across the membrane for analysis, and was required to circumvent the problems of the overlapping of GC peaks.

Masschelein (Belgium) asked Bilstad (Norway) to comment on the effect of temperatures, pressures and time on gas diffusion across the membrane.

Bilstad (Norway) replied that temperature is important and was kept constant during the diffusion process. Temperature was measured at the time of sampling and the sample was cooled and maintained at down to 0°C but not frozen. The analyses were always performed at a constant temperature maintained by an ice jacket. He added that the helium inside the stainless steel tubing and, therefore, also in the membrane loop is at a constant pressure because helium does not flow through the loop during the diffusion period since it is cut off for the two-minute period. During this time, helium diffuses through the membrane into the water (because there is no partial pressure of helium in the water) and dissolved gases in the water that do not exist inside a tubing dissolve into the tubing and would continue to do so until equilibrium was reached. But two minutes is insufficient to attain equilibrium. After two minutes the helium flow is restored to flush the gas plug into the GC. The flushing period was four seconds and was a function of the helium purge gas flow rate (20 mℓ/min) which can be controlled and the length of the stainless steel tubing (50 cm on each side).

Jones (Canada) commented that he was puzzled about the importance of measuring dissolved nitrogen and the mechanism at work in the plant which was neither nitrifying nor denitrifying but yet had nitrogen content of 118%

of saturation. He added that, in terms of nitrogen balance, once nitrogen has been converted into gaseous nitrogen, it is probably not significant whether it exists as a gas or as a supersaturated solution. Jones (Canada) also commented that, although the method of oxygen measurement is interesting and elegant, because of the two minute or more delay, it seems that one would have to be dealing with a system which is in complete equilibrium. If it is not possible to deal with a system which is transient in any way, the method has a very limited application in research where it is necessary to continuously or instantaneously measure the rate of change in oxygen concentration.

Bilstad (Norway) replied that the 118% saturation measured in the secondary settling tanks in the absence of nitrification or denitrification was due to the hydrostatic pressure in the aeration tank. Saturation values depend on the depth of air introduction. For example, at 5 m there are one and a half atmospheres of pressure and the driving force is increased accordingly ($(9\ \text{mg}/\ell) \times 1.5$). Therefore, it is not at all inconceivable to find 118% saturation of nitrogen in the settling tank. What is more difficult to explain is why it takes so long for nitrogen to approach equilibrium after it has become supersaturated. This is a big problem for aquatic life. Fish in water saturated at 118% of saturation with dissolved nitrogen can quickly develop a gas embolus and die. Thus, the states of Washington and Oregon have set limits at 105 and 110%, respectively, for dissolved nitrogen in rivers and effluents to protect salmon and other fish. However, 110% is the maximum value for salmon and trout. Bilstad (Norway) commented his technique was primarily for dissolved N_2 not O_2 and that excellent rapid techniques were available for measuring dissolved oxygen.

C. Paper No. 20: "Nutrients Removal and Recovery in a Two-Stage High-Rate Algal Wastewater Treatment System," G. Shelef, U. Azov, R. Moraine (Israel)

Shelef (Israel) discussed nutrient removal from wastewater by biomass accumulation. Removal of nutrients from wastewater effluents is necessary to control eutrophication in receiving bodies of water. However, less than 40% removal of nitrogen and phosphorus from strong municipal wastewater can be achieved via biomass incorporation in one-stage, high-rate algal ponds. Thus, the limiting factor for algal production in practical ponds is not the algal growth potential of municipal wastewaters in terms of nutrient availability but rather solar incident irradiance and temperature. Additional removal of nitrogen (up to 74%) from one-stage ponds can be achieved through atmospheric evolution of ammonia while 95% removal of phosphorus can be achieved by algal flocculation with alum. However, a multi-stage algal system is required to attain high-level removal of nitrogen and phosphorous via biomass incorporation. Use of a second-stage pond (following "coarse" separation by flotation of the algal biomass) yields an effluent (following "refined" separation of the algal biomass to remove the algae and suspended matter) containing less than 4 mg/ℓ of nitrogen and less than 0.5 mg/ℓ of phosphorus. Sand filtration is used to further polish the final effluent in order to use it for unrestricted irrigation.

Use of micro algae for nutrient extraction purposes is very efficient not only because they contribute almost twice their production in terms of oxygen added to the water but also because they contain 40-70% protein and protein is one of the commodities the world needs very badly. Thus, the algal biomass may be harvested from both stages and processed to yield a highly proteinaceous animal feed or protein for human consumption.

Shelef et al. (Israel) have greatly increased knowledge of intensive algae growth and harvesting. They have characterized bacterial and algal productivity and have shown that algal productivity undergoes expected seasonal variations while bacterial productivity is essentially independent of the season indicating independence with regard to irradiation and temperature. In addition, the nutrient material balance data and experimental results presented by the authors are most useful tools for nutrient recovery calculations and for the planning of high rate algae ponds.

As the effect of temperature on biological processes in wastewater treatment plants and in receiving waters is still controversial, Albrecht (Federal Republic of Germany) asked Shelef (Israel) if he would reveal the range of temperatures in which his productivity studies were carried out and whether the seasonal variation in algal productivity is primarily due to irradiation conditions or temperature variations. Albrecht (Federal Republic of Germany) commented that the effect of temperature on algae growth is sometimes overestimated, as there is a very close relationship between solar irradiation and temperature. In addition, small-scale studies indicate that algal growth rates are similar within the temperature range 5-25°C, if irradiation is kept constant. Albrecht (Federal Republic of Germany) noted that the authors conducted first-stage tests in a technical-scale pilot pond with continuous feeding while the second-stage tests were made in mini-ponds as batch tests and with semicontinuous feeding. He asked Shelef (Israel) if there are recent results which have been obtained from two-stage algal pond systems (in which both stages are of the same scale) with continuous feeding of both stages? If so, do these results differ significantly from those reported in the paper? He also asked what concentration of the aluminum chloride flocculant is used to harvest the algae and if any problmes are to be expected concerning salt enrichment in the final effluent? This latter question might be important with regard to water recycling, irrigation, and in arid countries with respect to high rates of evaporation and small receiving waters. In addition, he asked if other methods of algal harvesting have been studied such as micro-straining? Albrecht (Federal Republic of Germany) noted that it has been documented by several investigations that algae incorporate not only nutrients but also considerable quantities of heavy metals. And, recent studies have shown that even pure domestic waters may contain comparatively high concentrations of heavy metals resulting from corrosion of the conduit system. High concentrations of heavy metals could lead to undesired heavy metal loads in the harvested material. Albrecht (Federal Republic of Germany) asked if this might not restrict the use of harvested pond biomass as animal feed? He noted that the authors had stated that the value of harvested biomass is between $200 and $300 (United States) per ton and asked if these figures included all treatment costs (e.g., dewatering, drying and pasteurization). He also noted that the authors stated that their algal pond method was applicable only under warm climatic conditions where there is ample sunshine. However, he reasoned that this system might also be considered in northern countries for wastewater treatment facilities used only during the summer season such as camping areas. For this purpose, it would be of interest to know what the expected duration of the starting period of the algal pond system is and what the process stability is in terms of long-term variation of effluent BOD, COD, and other parameters. Finally, Albrecht (Federal Republic of Germany) asked for information on total area required per capita for the two-stage pond system.

Shelef (Israel) replied that bacterial productivity did not vary with temperature because the residence time for algae to grow is much longer than that for bacteria. Temperature, then, would not affect the rate of bacterial growth because they would have enough time to slowly incorporate and oxidize all the organic matter at these temperatures.

Shelef (Israel) stated that both irradiation and temperature affect algal productivity. In northern countries, for instance, low temperatures usually coincide with low irradiance and the combination results in low algal productivity. The idea that 5-25°C is the range for algae productivity is correct if the various species of algae are taken together. There are ocean-dwelling algae that grow very well at very low temperatures, while other species require higher temperatures for optimal growth.

With regard to the question of the effect of pond size on productivity, Shelef (Israel) stated that if the second stage had been of a larger scale, it probably would have yielded better results. Because of their size, the mini ponds tend to produce a lot of shading and lose heat by radiation.

Shelef (Israel) stated that they have used aluminum chloride as the flocculant at a level of about 100 mg/ℓ and that this added a considerable quantity of chloride to the effluent. However, they are using better flocculants now. One of the most promising is chitosan, a polysaccharide derivative of chitin which is obtained as a waste material from the shrimp and lobster industry. Shelef (Israel) mentioned that they had tried micro straining; but the algae are too small for micro straining.

Shelef (Israel) confirmed that algae do absorb heavy metals. However, they found that the heavy metals, especially those bound to phosphates, are practically inert and pass through the animals with minimal absorption. In effect, most of the heavy metals were recovered in the feces of the animals. In any case, the animals have a relatively short life (they are slaughtered for food), and the time available for accumulation of heavy metals in their tissues is minimal. In effect, there is no heavy metal problem.

Shelef (Israel) noted that $200-$300 (United States) per ton is the selling price for algae. The cost is less than that for soybean and fish meals on an equal protein basis. Shelef (Israel) stated that in northern countries such as Germany, algae could be grown in the summertime.

Shuval (Israel) asked Shelef (Israel) to comment on the extent to which nature plays havoc with the consistency of the process, especially with regard to the growth of the appropriate algal species. Shelef (Israel) replied that they have had few major problems with their system and have operated continuously without any shutdown.

Parker (Australia) aksed Shelef (Israel) to confirm that the organic loading on the initial pond is on the BOD order of 300-600 kg/ha·d to indicate the annual cost per unit mass of nutrient removal. Shelef (Israel) replied that, not considering the investment, the sale of algae covered only about half of the cost of the operation. However, because of the production of algae, the total cost of nitrogen removal was only 50 to 67 percent of that of alternative methods. Regarding organic loading, the 300-600 kg/hd·d range was correct. This means that the load on the ponds is four to seven times greater than that placed on regular oxidation ponds or lagoons and this requires a lot of area. However, the area required is only 1/4 to 1/7 of that which would be needed for oxidation or stabilization ponds.

Sandbank (South Africa) asked Shelef (Israel) if, in the situations with low nitrogen concentrations, the two-stage systems would be required. He also asked for comments on the alternative of removing phosphorus by flocculation instead of a second stage which would appear to increase losses by evaporation. In addition, he asked for comments on the application of the AGP bioassay outdoors.

Shelef (Israel) replied that in weaker wastes, such as those containing 25 mg/ℓ of nitrogen, 80-90% of the nitrogen could be removed.

He added that phosphorous most certainly can be removed by flocculation, but with the production of a very troublesome sludge. Shelef (Israel) highly recommended use of AGP tests to ascertain the necessity for removing a nutrient.

D. Paper No. 22: "Operational Management of Pollution Incidents--The Thames Way, UK," E. C. Reed, and M. C. Dart (United Kingdom)

Extension of the concept of integrated river basin management to the management of serious pollution incidents and the integrated management system employed in the U.K. to cope with such multidisciplinary problems were discussed. In addition, the development of a floating oxygen unit called the "Thames Bubbler" to improve oxygen levels in the tidal reaches as well as the upper parts of the Thames was discussed.

Phillip (France) discussed the importance of preventive measures as a means of reducing the incidence of water pollution episodes. It was indicated that in the aircraft and space industries, analyses of systems from the point of view of reliability and safety are the rule and suggested that those who are responsible for the operation and maintenance of water supplies should employ similar methods to reduce the probability of pollution incidents.

Philip (France) mentioned that a tricky problem in incidents of water pollution is not the sounding of an alarm as quickly as possible, but the ability to quickly and accurately diagnose a problem. He suggested that, where applicable, one method which could be employed in alleviating a pollution event in a river would be to decrease the concentration of the pollutants to an acceptable level by adjusting the rate of flow in the river. In this case, it is assumed that there are a number of storage reservoirs feeding into the river which could be tapped for this purpose.

IV. CRITIQUE OF SESSION

All papers in this session were of high quality and were well recieved by the audience as evidenced by informative discussions. The instrumentaton and techniques discussed in Paper No. 16 appear to be highly promising both for research and routine analytical purposes with smaller organic molecules (compounds produced by the reaction of chlorine with amino acids and other low molecular weight nitrogen-containing compounds). However, no information was available on the performance of the system with larger molecules. Utilization of the system in conjunction with mass spectrometry (MS) was discussed. Employing two-dimensional gas chromatography, trapping, and multiple injections for isolating and concentrating compounds prior to MS analysis is intriguing and of great promise with regard to the complete identification of potentially toxic (in the broadest sense) substances (especially minor contaminants of high toxicity) in drinking water.

Bilstad (Norway; Paper No. 18) described a membrane probe/gas chromatographic method for quantifying dissolved oxygen and nitrogen. Because the method was dependent upon diffusion, it is basically static in nature and cannot be utilized for kinetic measurements. In effect, it would have only limited application in research in which it was necessary to measure the rate of change in oxygen concentration either (or both) instantaneously or continuously. However, the technique appears to be excellent for quantifying dissolved nitrogen.

Shelef (Israel; Paper No. 20) described a highly efficient two-stage algal biomass accumulation system for the removal of nutrients from wastewater. Because the algae contain 40-70% protein, they can be harvested and processed to yield a high-protein animal feed or protein for human consumption. Concern was raised over the possibility of heavy metal uptake by the algae and the concentration of heavy metals in the protein-rich end product. Although no data were presented, Shelef (Israel) stated extensive studies have indicated no heavy metal-related problems with the animal feed. It would have been helpful if the details of these studies had been presented (including the quantity and kinds of metals and metal species present in the protein concentrate). Based on extensive heavy metal toxicology data and data regarding fish protein concentrates, the innocuity of the algal protein concentrate is highly questionable, especially in the case of monogastic animals. On the other hand, because of their food and unique digestive system, ruminants may be relatively less affected by the heavy metal content of the algal-derived protein concentrates.

The discussion (Paper No. 22) of the management system employed in the United Kingdom to cope with major river pollution episodes was highly informative, and most certainly, not controversial.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The applicability to United States water pollution research and monitoring problems of the two-dimensional gas chromatographic (GC) method for identifying and quantifying organic water contaminants described by Keith (U.S.A.; Paper No. 16) and the membrane probe technique for quantifying dissolved nitrogen described by Bilstad (Norway; Paper No. 18) should be thoroughly investigated. There is, for example, only limited information on the variety and nature of potentially toxic (in the broadest sense) chemical contaminants present in low concentrations in water used for human consumption. One reason for this has been the inability to identify such contaminants because their presence is masked by other compounds. Another has been the inability to accumulate sufficient quantities of these substances for characterization. It would appear that many such problems could be solved utilizing the two-dimensional GC technique, especially in conjunction with mass spectrometric analysis. It is to be stressed that identification and characterization of low-level contaminants in water used for human consumption is of importance not only because such contaminants may be directly toxic but also because some may act synergistically with other contaminants (major or minor) resulting in potential toxicity. The membrane probe/GC technique for measuring dissolved nitrogen appears to be especially applicable to surveying/monitoring environmental situations in which there is a potential for high-level dissolution of nitrogen which could lead to deleterious effects on a wide variety of aquatic life (e.g., food/game fish).

Use of two-stage algal biomass accumulation systems for the removal of nutrients from wastewater (Paper No. 20) may be highly feasible in a number of specific situations in the United States and should be investigated for its applicability.

I. SESSION

A. Day: Tuesday, March 30, 1982
Hall: A
Time: 1:00 to 4:35 p.m.

B. Theme of Session: Microbial Resistance; Wastewater Ozonation; Wastewater Phenolics

II. REVIEWER

A. Name: P. V. Scarpino

B. Position and Affiliation: Professor of Environmental Engineering
Department of Civil and Environmental Engineering
University of Cincinnati
Cincinnati, OH 45221

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 24: "Viability and Adaptability of *E. Coli* and Enterococcus Group to Salt Water with High Concentration of Sodium Chloride," by T. Omura, M. Onuma, and Y. Hashimoto (Japan)

The authors individually examined the viability of 10^5 to 10^8/mℓ of freshly isolated *Escherichia coli* and enterococci in synthetic sewage (having a BOD of about 100 mg/ℓ) containing 10 g/200 mℓ of NaCl to bring the concentration of NaCl to 5% (Wt/V). The survivors were subsequently regrown and inoculated into similar synthetic sewage containing NaCl to determine the adaptability of the organisms to salt water. *E. coli* was more sensitive to the salt water than the enterococcus group. *Streptococcus faecalis* var. *liquefaciens* demonstrated the greatest resistance of viability, and, of the enterococcus group examined, *S. faecium* showed the least viability.

Unlike *E. coli* type I, after repeated exposure of *E. coli* type II to salt water, its survival was changed from that of rapid die-away to one of multiplications. In addition, as *E. coli* type II was adapted to salt water it was replaced by *Citrobacter freundii* types I and II. Each member of the enterococcus group adapted differently to the salt water system. For example, although *S. faecium* had the poorest viability, it adapted well, whereas *S. durans* which showed greater viability in salt water than *S. faecium* could not be adapted to this environment. Both *S. faecalis* and *S. faecalis* var. *liquefaciens* also could be adapted to the salt water.

Types I and II of *E. coli* were detected near a sewage outfall (Station 1) in Miyako Bay, Japan, but were not isolated at Station 2 (about one kilometer from Station 1). Since both types I and II of *Citrobacter freundii* were detected at Station 2, this was believed to support the view that *E. coli* type II is adaptable to salt water. It was suggested that the isolation of *E. coli* types I and II may show recent water contamination, whereas the presence of *Citrobacter freundii* types I or II may show old contamination.

Furthermore, it was suggested that the isolation of *S. durans* from sea water might indicate recent contamination, while the presence of *S. faecalis* and *S. faecalis* var. *liquefaciens*, as well as *S. faecium*, may indicate old contamination of the sea water.

Grabow (South Africa), the invited discusser, pointed out that the findings of this study were of practical significance insofar as they indicated that the types of organisms in sea water can, in fact, give an indication of how far a sampling point is located from the actual source of pollution. In addition, although the findings were interesting, it was important that some information on the underlying mechanisms involved in adaptation to saline resistance by the microbes be included. However, the paper did not give a great deal of information concerning mechanisms of resistance development. This information is important to evaluate the behavior of other organisms in this environment and to evaluate the indicator significance of *E. coli* and other coliforms, as well as streptococci as indicators of fecal pollution of sea water. The following additional points were made: What has been described as adaptation were in fact genetically-stable mutations to increased resistance in an unfavorable environment. Grabow (South Africa) was surprised that closely related bacteria gave different adaptability (or mutation) responses. He suggested that *Citrobacter freundii* should also be isolated from sewage and their viability tested in a similar high salt water environment. Also, he suggested that the differences between Gram-negative and Gram-positive bacteria to high saline concentrations may differ extensively, because the *E. coli* type II organism that underwent change to *Citrobacter freundii* had accompanying change in their ability to produce indole and utilize citrate whereas the Gram-positive streptococci showed no such changes. What is important is that we are dealing with organisms which have actually undergone genetically stable mutations. Information on the possible differences between saline-sensitive and tolerant strains may be enhanced if more information was available on other properties of these organisms such as their morphology, growth rate in broth, the composition of their cell walls, and the ability to grow at 44°C. Grabow (South Africa) concluded by emphasizing that this paper was important because it was in an area of prime importance, i.e., the ability of microorganisms to adapt to unfavorable environmental conditions, and related to the selection of resistant strains which may play an important role in water treatment processes.

Omura (Japan) replied to a question by Filip (Federal Republic of Germany) conerning the composition of synthetic sewage by noting that it contained a BOD of 100 mg/ℓ and included sufficient nutrients. Filip (Federal Republic of Germany) indicated that *E. coli* is used in Germany as an indicator of fecal contamination of swimming pools filled with sea water and that the resistance of fecal streptococci to salinity is well known. For example, in normal microbiological diagnostic practices, the growth of fecal streptococci in nutrient broth containing 6.5% NaCl is used as a characteristic criterion for the identification and isolation of fecal streptococci. It was suggested that perhaps another bacterium would be better used in his studies instead of the fecal streptococci.

Shuval (Israel) noted that the paper was germane at this time when we are concerned with a particular pathogen that is known to be quite tolerant to sea water, i.e., the cholera vibrio. The latter can possibly be transmitted to man via shellfish. Thus, the search for microbes that mock or parallel such resistant pathogens is quite germane. However, the primary mechanism for inactivation of coliform microbes in the sea is not the chemical composition of the sea water, but is due to light effects (i.e., either photosensitation or photo-oxidation). The actual role of the inactivation of coliforms by the composition of the sea water is a relatively minor factor in the overall protection of beaches. This does not negate, however, the importance of this present study. Nevertheless, the salt content of sea water plays only a small part in inactivation in sea water under real-world conditions. The present studies were carried out in the laboratory in dark incubators, thus negating the effect of the light on inactivation. Finally, Shuval (Israel) pointed out that the nutrient environment provided in the study was too rich a menstruum for the development of the bacteria. Omura (Japan) responded that high BOD levels were used in his study to allow the added bacteria to reproduce, and thus allow easier detection of bacterial resistant to salt water. Shuval (Israel) replied that he would like to see studies on the presence of photo-sensitive resistant organisms in the sea.

Gameson (United Kingdom) replied to Grabow (South Africa) and pointed out that the effect of radiation on bacterial mortality in the sea was not confined to the ultraviolet range only. Long-wave ultraviolet and short-wave visible light (halfway through the visible spectrum) also has a lethal effect on coliform bacteria. The shorter the wave length, the greater the lethal effect, but the smaller the quantity of radiation available.

B. Paper No. 26: "Chlorine-Resistance of Coliform-tested Bacteria Isolated from Raw and Treated Sewage Effluents," by L. V. C. Leong, D. Otsaka, H. F. Ridgway and B. H. Olson (U.S.A.)

Two hundred and seventy-four bacteria, predominately coliform organisms, isolated from sewage treatment effluents were screened for relative resistance to combined chlorine using a disc-assay procedure. Bacteria isolated from tertiary chlorinated effluent were the most resistant to combined chlorine according to the assay procedure. *Escherichia coli* was the predominate organism isolated from the unchlorinated sewage treatment processes and ranked fifth of 12 genera in resistance to combined chlorine, while *Enterobacter* sp. was the dominant bacterial genera isolated from chlorinated tertiary effluent and was the most chlorine resistant.

In formal discussion by Vial (France), the disc-assay technique for chlorine resistance was questioned. The discusser asked if the chlorine resistance found was a natural species-resistance or was it an acquired resistance of the plasmid type. He pointed out the importance of the phenomenon of microbial chlorine resistance and its implications. This and other work should influence attitudes toward disinfection of wastewater because of the possible selection of microbes which are chlorine resistant. Thus, he was skeptical about the disinfection of wastewater since it might scatter in nature resistant strains of not only fecal indicators but also pathogens. Also, the development of resistant microbes might make it difficult to treat effluents later on if it is absolutely necessary to do so.

Leong (U.S.A.) responded that chlorine resistance was genetically stable since the growth of the initially isolated chlorine-resistant bacteria went through several passages and still maintained a resistant pattern. The exact mechanism of resistance (i.e., plasmid associated or otherwise) is unknown at this time.

Filip (Federal Republic of Germany) emphasized that he was skeptical of chlorination of effluent, although some (but not all) pathogens are inactivated. Chlorination cannot only cause the development of chlorine-resistant microbes, but the process can as well cause mutagens to be formed. Filip (Federal Republic of Germany) also questioned the technique used to evaluate chlorine resistance. Also, the authors of the paper did not carry out any genetic tests but still claim the development of genetically-stable bacteria.

Leong (U.S.A.) pointed out that although the test technique used might have flaws, it is extremely useful in screening large numbers of bacterial colonies for chlorine resistance. Grabow (South Africa) had reservations about the test techniques used to establish chlorine resistance. He pointed out that the process described is one of selection, not of mutation.

C. Paper No. 28: "Ozonation of Aromatic Compounds: pH-Dependence," by E. Gilbert (Federal Republic of Germany)

The ozonation of 2-nitro-p-cresol and p-toluenesulfonic acid ($C = 1$ mmole/ℓ, ozone dose = 10 mg/min·ℓ) in aqueous solution tion as a function of the pH-value (pH = 2.5 - 10.5) was investigated. At a pH of 2.5, the reaction products of 2-nitro-p-cresol were measured quantitatively over the run of the reaction.

Elimination rates for initial compounds and the mineralization of the heterogroups increased with pH value. On account of this result, the spectrum of oxidation products is different after 90% elimination of the initial compound as a function of pH. The values of DOC- and COD-elimination increased with increasing pH. Although the ozone absorption was better in the basic range, 1.6 - 2.2 mg O_3/mg ΔCOD are required in the basic range (pH 10), but only 1.1 mg O_3/mg ΔCOD in the acid range (pH 3).

Gilbert (Federal Republic of Germany) discussed ozonation of substituted aromatics in aqueous solutions, how reactions involving ozone proceeded, and which reaction products could be expected, depending upon the elimination of the initial compound and the pH value. Besides, he examined how much ozone was needed to eliminate the COD and to increase the BOD values.

The invited discusser, Schalekamp (Switzerland), reviewed the highlights of the paper. He emphasized that the most important results of this study were: In the ozonation of aromatic substances in aqueous solutions, the pH value plays a very important part, i.e., the rate of elimination of aromatic compounds increased with rising pH, along with a 2-1/2 times increase in the degradation of DOC and COD and the mineralization of the hetero groups. Earlier research demonstrated that other organic substances, e.g., humic acids, are better eliminated by ozone at a higher pH value. Thus, a higher pH value of the water means better oxidation. Additionally, because the pH value plays such an important role during the ozonation of the organic compounds, it is absolutely necessary when comparing the results of ozone effects to indicate ozone dose and consumption and the corresponding pH values of the investigated aqueous solutions.

D. Paper No. 30: "Presence of Phenolic Compounds in Sewage, Effluent and Sludge from Municipal Sewage Treatment Plants," by F. B. DeWalle, D. A. Kalman, D. Russell, D. Norman, E. S. K. Chain (U.S.A.)

A total of 25 municipal sewage treatment plants were sampled, 10 of which were resampled, to determine the quantity of phenolics in sewage, final effluent and anaerobically-digested sludge using capillary GC/MS/DS techniques. The study noted in decreasing order of frequency in raw sewage: phenol, pentachlorophenol, dimethylphenol, 3-methyl, 4-chlorophenol, 2,4,6-trichlorophenol, 2,4-dichlorophenol, 2-nitrophenol, 2-chlorophenol, 2,4-dinitro-6-methylphenol and 2,4-dinitrophenol. The maximum concentration of phenol in sewage and sludge was 2800 ppb and 4460 ppb, respectively, while similar values for pentachlorophenol were 58 ppb and 1200 ppb. Statistically calculated concentration reductions for phenol and dimethylphenol were generally greater than noted for tri- and pentachlorophenol. Low decreases or increases were noted for monochlorophenol and especially for dichlorophenol as a result of the chlorination of the final effluent.

Osborn (South Africa) presented the formal discussion and raised several points dealing with the sensitivity of the detection method. He pointed out that although the authors indicated that higher influent concentrations of phenol resulted in a higher residual phenol concentration in the effluent (attributed to a possible toxic effect), this did not seem likely since activated sludge has been frequently used for the treatment of effluents high in phenol from coal gasification.

IV. CRITIQUE OF SESSION

The papers in this session were not uniform in either theme or in quality. Papers No. 24 and 26 dealt with the development of salt-resistant and chlorine-resistant microbes, respectively. The authors discussed the development of resistance, but in one case resistance was believed to occur by adaptation (Paper No. 24), whereas in the other resistance was acquired by a selection process that produced genetically stable bacteria (Paper No. 26). Paper 24 was at one point a rediscovery of the use of NaCl to isolate streptococci, and, along with other problem areas, pointed out an important fact, that although the investigators had an excellent purpose, they were not microbiologists. Paper No. 24 elicited a vigorous floor discussion, in spite of itself.

Paper No. 26 was a valuable contribution to the literature and was well received by most of the delegates. However, there was criticism of their use of "genetically stable" without sufficient proof to several that this was so.

Paper No. 28 was the masterpiece of the session. Gilbert (Federal Republic of Germany) carefully unfolded an excellent, well-constructed scenario highlighted by excellent slides and a good manner of presentation.

There was much to congratulate Paper No. 30 about, but some were dissatisfied with the methodology used. However, most felt that it was a definite contribution to the literature in this area of phenol removal. It was unfortunate that no microbiological investigations were conducted at the same time since they might have proven invaluable in an understanding of the removal efficiencies.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

All of these papers are a contribution to the literature, and we can learn much from them. Papers No. 24 and 26 focus attention on the important area of development of resistant microbes, whereas Papers No. 28 and 30 deal with the interaction of ozone with substances in water and the presence and movement of phenols through municipal sewage treatment plants, respectively.

Papers No. 24 and 26 point out the need to more thoroughly be aware of the developments under stressful conditions of resistant microbes in the water environment, either by a selection, adaptation, or actual mutational process. It will be important to know more about resistance developments in natural or man-made environments, since pathogenic-resistant microbes can ultimately be a danger to the public. Several times adverse comments were made by delegates about chlorination of sewage and the possibility of producing resistant pathogens. It is important that we assess such developments to determine their real costs and benefits and to re-evaluate procedures if warranted.

The results of Paper No. 28 will find increasing usefulness as we further examine the use of ozone to remove organic compounds from wastewaters. The work of this author should be carefully followed, since he is carefully investigating the factors affecting ozone interactions with compounds.

The last paper, Paper No. 30, provided useful information to those in charge of industrial effluents since it focused on the removal of phenols through treatment plants. As we clean up our influents to treatment plants, such information will continue to be increasingly valuable.

I. SESSION

A. Day: Thursday, April 1, 1982
Hall: A
Time: 9:00 a.m. to 12:30 p.m.

B. Theme of Session: Assessment and Control Strategies for Water Quality Management

II. REVIEWER

A. Name: A. J. Englande, Jr.

B. Position and Affiliation: Associate Professor and Chairman
Department of Environmental Health Sciences
Tulane University School of Public Health and Tropical Medicine
New Orleans, LA

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 32: "An Appraisal of the Performance of a Continuous Automatic Fish Biomonitoring System at an Industrial Site," by W. S. G. Morgan, P. C. Kuhn, B. Allais and G. Wallis (South Africa)

The paper described the application of a continuous automatic fish biomonitoring system employing fish locomotory behavior patterns as measured by means of ultrasonic echoes to monitor acute toxic discharges from a pulp and paper mill. The system was capable of monitoring either five or ten independent channels, each consisting of a specifically-designed sensor chamber containing one fish (guppy) through which a continuous flow of test water was passed.

The guppy was selected as the sensor fish due to its sensitivity to a wide variety of pollutants and its ease of maintenance. Increased fish activity (counts/h) above the 95% confidence limits established for normal activity levels indicated a potential toxic condition. Feed water consisted of river water upstream of the plant, dechlorinated influent mill water, and mill effluent diluted to a concentration equivalent to that of lowest recorded river flow.

Advantages of the biomonitoring system included: (1) continuous, immediate response to toxic spills versus the noncontinuous output of physical-chemical analyses; (2) response to the totality of the environment considering synergistic and antagonistic actions; and, (3) response to acute toxicity as well as to some chronic toxicants.

During the twelve months of evaluation, only one fish kill was experienced in the river of study. Information from the sensors helped regulatory officials to conclude the industry was not responsible, hence avoiding possible litigation. Cost of system installation was approximately R35,000 ($35,000 U.S.A.); whereas operation and maintenance costs totalled R3,350 during the year of the study. Enhanced public relations for the industry were a benefit.

The formal discusser, Yoshida (Japan), noted that continuous biological monitoring was essential and equal in importance to chemical analysis in assessing impact to the aquatic and human ecosystem. From an ecotoxicological viewpoint, organisms employed should represent those common in the food chain within the ecosystem, including single-cell algae, daphnia and fish. In Japan, fish are commonly used as sensors to toxicants since fish represent a major portion of protein supply. While fish are easier to evaluate than many organisms, it must be noted that response to toxicity is dependent on physiological conditions, e.g., species, age, sex, spawning, and nutrition. The discusser also indicated that in Japan, the systemized methodology presented by the author is generally not practiced. Fish are typically observed visually for toxic effects in ponds and drainage channels containing industrial effluent. The species employed is selected based on the specific industrial wastewater.

The discusser commented on the low dissolved oxygen content of the mill effluent (3.3 to 2.4 mg/ℓ) and to lack of control of water temperature. He also noted that the visible light beam method was usually used to monitor locomotion, and that more data are needed to evaluate the effects of fish sensitivity to ultrasonic waves.

Morgan (South Africa) agreed with the concept of considering a multitude of species (the guppy was more sensitive than other fish downstream in this case) and using a battery of biomonitoring tests which are done at the National Institute for Water Research. Under the conditions of this study, as much standarization was done as possible, i.e., use of only males. He also replied that the oxygen content was maintained at a level of that existing below the discharge point and not that of the mill effluent. The author noted that toxicity varied with temperature and, therefore, it was more accurate to use ambient temperatures. No effect due to ultrasonic waves on fish physiology was noted following a six-month exposure. It was emphasized that it is important to determine where biological monitoring fits into control situations and into legislation, particularly for industries who apply for permit exemption. It was emphasized that the method reported eliminated the observor and indicated stress on the sensor animal which yielded advanced warning of critical conditions.

In floor discussion, Jones (Canada) questioned the type of toxicity which was measured. He also noted that a direct and linear relationship was assumed between concentration of toxicant and fish activity, and that toxicants may reduce activity which would not be measured by the system proposed. Jones (Canada) stated that increased temperature may cause a false alarm due to increased metabolism. Morgan (South Africa) replied that the method did not detect genetic effects, but measured only acute toxicity and some chronic effects. Metabolic variance in fish was considered by a lengthy standardization process. It was noted that a running statistical method (i.e., day to day) could be employed but would be expensive.

In other floor discussion, Josso (South Africa) commented that while the reported system was excellent, it was only a warning method which identified pollution, as do other systems. He concluded that no specific system should be included in the Water Act to force people to use a unilateral approach.

Handleman (U.S.A.) questioned whether the method proposed was sufficiently sensitive to detect trihalomethanes or other particular constituents of concern at the site of evaluation. Morgan (South Africa) replied that bleaching was not practiced at the site; therefore, THMs were not a problem.

From the floor, Haboll (South Africa) asked what was the lowest concentration of toxicants which could be detected by the system. The author answered that generally, 10% of the lethal level (96-h LC_{50}) is detected, but no absolute concentration can be given.

One participant inquired about the preferred ultrasonic frequency. Response from one of the authors indicated that 100 kilohertz was selected at 1 milliwatt. These frequencies were selected based on preliminary test results and availability of suitable sensors.

B. Paper No. 34: "Examination of a Drinking-Water Supply for Mutagenicity," by P. G. van Rossum, J. M. Willemse, C. Hilner and L. Alexander (South Africa)

The paper described the results of an Ames-test survey of drinking-water sources in Pretoria. Single samples were tested from 18 locations and water constituents from an additional sampling point were analyzed for mutagenic effects monthly over an eight-month period. 'Characterization Tests' of each sample consisted of pH, chlorine, optical density and electrical conductivity determinations. After unconcentrated water samples indicated no mutagenicity, subsequent samples were concentrated by passage through XAD-2 resin columns followed by desorption with acetone.

Mutagenic activity was observed in samples from 14 of the 19 sampling points as well as consistently demonstrated in the monthly testing. All mutagenicity was observed with strain TA 98 and was not detected with strain TA 100 indicating that the mutation was frameshift. Mutagenicity was observed to a greater extent in plates without the S-9 enzyme activation system, which may indicate a detoxification or inactivation by these enzymes. No correlation was found between mutagenicity and volatile halogenated organics, polynuclear aromatic hydrocarbons, or 'characterization tests' results. Liquid-liquid extraction samples gave essentially the same mutagenicity results as those with the adsorption extraction method.

The formal discusser, Hartemann (France), commented that the results were not in total agreement with those from his research experiences in France. His remarks took the form of a series of questions which included: (1) Was follow-up work done to identify the mutagenic compounds by GC/MS?; (2) Is the mutagenic activity decreased by activated carbon or ozonation?; (3) Were the Ames test results confirmed by other tests?; (4) Were other elutriates aside from acetone evaluated?; (5) Which toxicity tests should be employed for preliminary screening?; and (6) How does one express mutagenic activity at different concentrate dilutions? Hartemann (France) concluded by underscoring the lack of correlation between mutagenicity and the presence of chlorinated compounds. He also indicated he was disappointed that the authors did not cite the work of the group in the Netherlands.

In response, Van Rossum (South Africa) replied that since the work reported was completed, concern has shifted to isolating the substance(s) causing the mutagenic activity. Work has focused on developing an extraction procedure considering stability, volatility and whether the compound is neutral, acidic or basic. Results indicated that compound(s) producing mutagenicity were probably organic acid(s). The resin was changed to XAD-7 which yielded slightly better results. The compound(s) were sorbed to activated carbon and not desorped with acetone. No work was done with ozone. Other toxicity testing was done including tissue culture. Acetone was used due to its low boiling point and to prevent artifacts and contamination. The negative results observed with TA 100 as compared to TA 98 corresponded to those obtained by Hartemann.

Philip (Federal Republic of Germany) commented that use of more than one sample from each location would increase the confidence of the conclusions, to which the author agreed. In addition: (1) What non-mutagenic solvents were used?; (2) Why were mutagenic activities higher without the S-9 mixture?; and (3) Could UV absorbance be a function of mutagenic activity? van Rossum (Federal Republic of Germany) replied that acetone was used for adsorption extraction and dichloromethane for liquid/liquid extraction. After obtaining preliminary results, adsorption extraction was determined to be the preferred method. He also indicated that increased mutagenicity without the S-9 enzyme activation system may suggest a detoxification or inactivation by these enzymes and therefore the isolated constituent(s) may not pose a health concern.

Grabow (South Africa) made several comments from the floor. These included: (1) the XAD extraction procedure is selective and will not concentrate certain compounds, particularly, very polar compounds; (2) If one uses non-concentrated water, mutations can be achieved with both TA 98 and TA 100 strains; (3) If toxic effects do occur, one can dilute to non-toxic, but mutagenic levels, and draw a dose-response curve; (4) Good correlations were achieved between the Ames test results and those from tissue culture; (5) THMs were not measured by the technique used for the Ames test since volatiles were lost when samples were evaporated to dryness; and (6) Organic compounds in water do increase UV sorption and mutagenic activity.

C. Paper No. 36: "Depositional Process of Fine Sediments," by T. Kusuda, T. Umita, K. Koga, H. Yorozu and Y. Awaya (Japan)

Depositional properties and projected sediment quantities were determined from experimental and theoretical studies using fine less-cohesive sediments (silt) typical of Japanese estuaries and bays. The experimental apparatus consisted of a rotating annular channel and an annular ring. The ring was rotated in the opposite direction to the channel at related speeds with regard to different shear stresses to minimize secondary current effects.

The suspended fine sediment concentration was found to depend on shear stress with critical particle diameter corresponding to shear stress. The steady-state concentration (those particles remaining in suspension) at the final stage of deposition was determined by the quantity of particles smaller than those possessing the critical diameter. The deposition rate of sediments was found to be predictable and dependent on size distribution, critical diameter and concentration of settleable sediments. Sedimentation occurred rapidly within 22 hours. The suspended particles smaller than the critical diameter were observed to be held in water without settling for extended periods.

The formal discusser, Davis (South Africa), considered the work to be reliable and valuable within the constraints of the experiment. His question dealt primarily with applicability of the proposed model. Since most estuaries and bays undergo daily tidal changes, the velocities and shear stresses are dynamic; consequently, deposition rates and quantities are constantly changing. It was noted that resuspension of the sediment was not considered by the authors, thus, neglecting an important phase of the process.

The author responded that shear stress does change with time due to velocity changes; hence, critical diameter and the final suspended concentration also change. However, some estimation of deposition can be obtained by using an equation presented in the paper. He also noted that while erosion does occur, particles settle readily following reduction in velocity.

Simpson (South Africa) questioned the details of the annular flume operation which was explained by the author. He also questioned the particle size distribution measurement technique and specifically, whether any measures were taken to remove chemically sorbed contaminants from the silt or if apparent size was reported. The author responded that a hydrometer test, which utilizes a rotating disk to measure size distribution by use of centrifugal force to accelerate the settling velocity, was employed to determine particle size distribution.

D. Paper No. 38: "Nutrients and Algal Growth in an Impounded River. Consequences for Its Oxygen Balance and Nutrient Control Strategy," by K. R. Imhoff and D. R. Albrecht (Federal Republic of Germany)

It was reported that a series of impoundments on the final 45 km of the Ruhr River caused heavy algal blooms which proved detrimental to the treatment capacity of downstream water works. Phosphorus, nitrogen, and organic carbon concentrations were high and an oxygen shortage was recorded in the river following algal decay at low flows which required artificial aeration. A balance of oxygen supply and consumption indicated that 2/3 of the oxygen demand was due to algal decomposition. Assessment of water quality data from the past 30 years as well as results from special laboratory evaluations indicated that phosphates initiated algal growth. A phosphate model was developed for the river which predicted phosphate content for the years 1988 and 1998. It was projected that by the reduction of phosphate, maximum algal growth could be cut by about 50%. This assumed a phosphate concentration of 0.5 mg/ℓ. Capital investment for phosphate reduction by chemical precipation was calculated to be low and was, therefore, encouraged.

The first formal discusser, Rivas (France), questioned whether the most cost-effective method of dealing with the problem would be the elimination of nutrient problem at the source or at the water treatment plant. The first approach was recognized as the most desirable. Questions dealt with the oxygen balances, artifical aeration and whether ammonia removal would be more successful in confronting the eutrophication problem. The author replied that five continuous oxygen measurement stations were evaluated on a daily basis. He also noted that artificial aeration was only provided when the oxygen level dropped below 4 mg/ℓ. Nitrogen content was not considered a limiting factor based on data and experience.

Vivier (South Africa) was impressed with the monitoring and control of the reported control system. Critical areas of questioning included: (1) Modeling of limnology processes in impoundments with short detention times; (2) Quantitative account of algal removal vs costs; (3) Laboratory evaluations vs actual P-removal and (4) cost/benefit analysis. The author replied that the model proposed was based on data collected for the system considered. Precipitation of phosphorus was only necessary during low-flow conditions and could be accomplished at a relatively low cost.

Moller (Federal Republic of Germany) questioned the type of treatment proposed for P-removal. Imhoff (Federal Republic of Germany) responded that larger activated sludge plants should first be modified to reduce the critical nutrient.

IV. CRITIQUE OF SESSION

The session dealt with various assessment and control strategies for water quality management. Owing to the wide variety of topics covered, each paper will be critiqued individually.

Paper No. 32. If there are good experimental data to prove that there is a true cause-and-effect relationship between a specific pollutant and some aspects of behavior, then the biomonitoring system as described (and with the limitations so stated) is a useful idea. However, only acute toxicity of the effluent in general can be assessed. Morgan et al. (South Africa) recognized after a one-year trial that effluent concentrations having a long-term chronic effect, may or may not be detected by in-plant biomonitoring system, and have initiated work on growth and reproduction. One must await evaluation of new data before a proper determination of these aspects can be made.

The authors emphasized the effluent treatment improvements effected at the paper mill between August, 1979 and August, 1980. While improvement with respect to COD was made, there was no improvement in reduction of suspended solids or dissolved solids. It is suggested that increased use of secondary treatment be encouraged on the theoretical premise that the additional treatment would result in an improved dissolved oxygen profile (and lower BOD) and ultimately an improved and more rapid rate of growth for native fish in the Tugela River.

Paper No. 34. The paper reports good preliminary work which was well perceived and thought out. The procedure employed has been previously used to concentrate mutagens from the urine of cigarette smokers. Taking multiple samples is an important aspect of any environmental assessment. However, mutagenicity assays were done on only one of every three samples. The statistical significance of the results would be greatly increased if all samples had been assayed.

The use of columns to remove and concentrate organics from large volumes of water is very promising. However, as indicated by the results, the column used for this study did not adsorb all mutagenic compounds since passing the water through a second column occasionally yielded significant mutagenic activity. An assessment of the recovery efficiency (possibly using TOC) would help in evaluating column adsorption as a viable concentration procedure for mixed environmental samples.

It would be more legitimate to state that this mutation is a frameshift, if all four commonly-used Ames strains had been used in these assays. This reduces the problem of the varying sensitivities observed among the strains. No speculation is offered as to the lack of correlation between levels of halogenated organics and polycylic aromatic hydrocarbons and mutagenicity results. This could be an example of synergism and/or the presence of promoting agents in the water which would augment the mutagenic activity of low level mutagens.

Paper No. 36. The study represented an excellent initial stage of determining sedimentation and erosion mechanisms in bays and estuaries. Laboratory and theoretical work will ultimately have to be tested for practical application where dynamic conditions occur. Further work on describing the erosion process will undoubtedly be required to complete model applicability.

Paper No. 38. A data base of 30 years combined with the results from special laboratory evaluations strongly support the conclusion that phosphates were responsible for initiating algal growth for the Ruhr River. It must be noted, however, that selection of phosphorus, nitrogen, carbon, or other parameters as the critical nutrient for control will be site specific depending on the water body under consideration.

The oxygen balance technique vividly illustrated problem identification and necessary control measures to be initiated. There is concurrence that control of the problem nutrient should be done at its source. Applicability and final evaluation of the phosphate model accuracy can only be determined following implementation of phosphate control measures.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The information presented during this session dealt with various aspects of assessment and/or control strategies for water quality management. The four papers significantly contributed to existing knowledge in this area and all, to at least some extent, are applicable to on-going research activities in the United States. Papers will be addressed separately.

Paper No. 32. The proposed system is relatively inexpensive and requires minimal skill in operation, thus rendering it of wide potential applicability throughout the United States for specific industrial discharges. It can indicate continuous acute, synergistic and antagonistic lethal biological effects of effluents to specific fish species. While output limitations may be significant, it does offer an additional tool useful in water quality management.

Paper No. 34. There has been increased concern in the United States about the presence of suspected mutagens and carcinogens in the drinking water of many industrialized areas, but work in this area has been limited. This paper provided further evidence that mutagenicity screening is an important aspect of water quality management. The procedure as discussed by the authors would be an ideal prescreening assay which would indicate whether further isolation and identification of specific compounds is necessary. The paper demonstrated the need to examine the mutagenic potential of potable water where there is suspicion of contamination by waste organics.

Paper No. 36. Where sediments are largely of noncohesive sediments (silt), the study provided insight into the significant parameters which affect sediment deposition. This is of importance in hydrodynamic studies and coastal engineering evaluations. The maintenance of desired water depths for navigation is of course critical to the shipping industry of the United States and other countries of the world. This work is particularly applicable to river outlets and estuarine areas where silt predominates.

Paper No. 38. Monitoring and system control reported in this paper is impressive and perhaps could be employed at site-specific locations within the United States. The method of problem identification appears to have wide applicability; however, phosphorus will not always be the controlling nutrient. Other factors (physical, chemical and biological), besides nutrient content, must be considered. Much money is spent annually for nutrient control within the United States without comprehensive evaluations for justification. This study is useful for designing and implementing such comprehensive assessments.

I. SESSION

A. Day: Thursday, April 1, 1982
Hall: A
Time: 2:00 to 5:35 p.m.

B. Theme of Session: River Water Quality; Sediment-Water Interactions

II. REVIEWER

A. Name: Gerard A. Rohlich

B. Position and Affiliation: Professor of Environmental Engineering
University of Texas
Austin, TX

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 40: "Impact of Nuclear Power Plants of the PWR-Type on River Water Quality," by W. J. Masschelein and J. Genot (Belgium)

The paper summarized and analyzed the impact of a pressurized water reactor (PWR) nuclear power plant on water quality in the Meuse River. The river is the raw water source for about 5 million persons in France, Belgium and the Netherlands. The data were based on five years of experience at the Tailfer water treatment plant in Belgium. The Tailfer plant is located 48 km downstream of the PWR nuclear power plant of 320 MW(e) located at Chooz. A principal purpose of the study is to provide guidelines for examination of the impact that installation of additional nuclear plants, now in the planning stages and totaling 5400 MW(e), will have on water quality in the Meuse River. Four impact factors were considered including: (1) reduction in water flow; (2) thermal impact; (3) discharge of nuclear active effluents; and, (4) physico-chemical impact through enrichment in salts and suspended matters.

Analysis of the hydrologic data indicated that, when full capacity of the power plants at Chooz is realized, the immediate loss in water flow in the river may amount to 4 m^3/s. This is equal to an annual loss in flow of 87×10^6 m^3. This deficit was considered to be critical for navigation, industrial, and general uses downstream and would have to be restored by appropriate reserves so as to maintain the required flow conditions. The installation of PWR power plants of high capacity, requiring cooling water from rivers subject to low-water levels such as the Meuse, would make it necessary to provide sufficient storage to provide adequate water flow downstream of the power plants.

At full power-plant capacity at Chooz, the increase in water temperature at Tailfer was predicted to be less than 1°C and generally about 0.5°C. The amplitude of the temperature increase at Tailfer will be within the normal variation of the diurnal cycle. Although as yet there has been no definite indication of effect of temperature on the biota in the river, the authors recommend that water temperature immediately downstream of the nuclear site (e.g., 1 km) not exceed 30°C and see a potential need for installations to provide supplementary water to the river flow to guarantee that the 30°C limit is not exceeded.

Tritium activity in the Meuse River was measured every two to three days in "average" samples, and particle-fixed radioactivity was measured monthly on samples collected continuously. Chemical pollutants from the power plant mainly derive from the cooling and heat transfer circuits. The principal products of concern are chlorinated compounds, trihalomethanes (THM), and sulfate (resulting from use of sulfuric acid for de-scaling).

Using the data obtained over the five-year period as a basis for prediction of water quality when proposed power plants are fully developed, the authors propose the following guidelines:

(1) Accurate information is required on average and duration curves of water flow and particularly instantaneous flows from power plant during critical low-flow periods in the river.

(2) The most active effluents including tritium appear sufficiently low in volume to consider their transport to other sites.

(3) River water quality should be based on measurement of tritium, total γ activity and Co^{60}, Cs^{137}, Mn^{54}, Co^{58}, and Cs^{134}.

(4) License for nuclear discharge should be based not only on "maximal admissable dose" over an integrated period, but also on "instant maximal volume concentrations."

(5) Anti-fouling treatment through pulse chlorination is a questionable practice producing THMs at levels higher than acceptable.

The invited discusser, Henry (Australia), expressed the opinion that biological effects of the power plant discharges should be given more attention. Changes in the biological community may affect the ability of the biota to take care of other discharges, and if a viable fishery exists, it could also be affected adversely. The author responded by stating that the Meuse is used for sport fishing but there is no commercial fishery, and that as yet there is no clear evidence that the biological community has been affected. There is some evidence that tritium in algae is 15 percent higher than the water column.

The author reported that the radium content of the intake water at the Tailfer plant was 0.08 nCi/m^3. In response to a question as to what portion of this was natural, the author stated that the natural level was 0.02 nCi/m^3, and thus the maximum contribution from the present power plant was 0.06 nCi/m^3. A question was asked concerning the amount of wastewater from the power plant from leaky valves and fittings that was not being monitored. This amounts to about five percent, and radioactivity in atmospheric fallout amounts to less than ten percent of the total liquid discharge.

B. Paper No. 42: "Fractional Composition of Phosphorus Forms in Sediments Related to Release"
by H. Furumai and S. Ohgaki (Japan)

The purpose of the study was to investigate the characteristics of the various forms of phosphorus in sediments in an effort to clarify the relation between the fractional composition of the phosphorus forms and phosphorus release.

Two series of experiments were conducted, one using sediment samples taken from Takahama Canal near Tokyo Bay. The canal receives about 10^6 m^3/d of effluent from a secondary sewage treatment plant. The water in the canal is a mixture of sea water and effluent. The second series used sediment samples from Lake Kasumigaura, a eutrophic lake which receives a heavy load of organics and nutrients from polluted rivers.

Phosphorus release from sediments was investigated by placing sediment samples in bottles and incubating the samples in the dark at a constant temperature of 30°C. The canal samples were covered with artificial sea water, and the lake samples with filtered lake water. In the series using sediment from the canal, five samples each with one added phosphate compound and a control were investigated. Phosphate compounds added were KH_2PO_4; $Fe_3(PO_4)_2 \cdot 8H_2O$; $FePO_4 \cdot 4H_2O$; $AlPO_4 \cdot 2H_2O$; and $Ca_{10}(PO_4)_6(OH)_2$. The lake sediment samples were sliced from cores and sediments from depths of 0-4 cm, 6-10 cm, and 20-24 cm were used. Phosphate compounds were not added to the lake sediment samples.

After a predetermined and varying number of days, overlying water was withdrawn by pipet, filtered and analyzed. Sediment was then centrifuged at 300 rpm for 10 min and supernatant liquid removed. Centrifuged sediment was used for phosphorus fractionation. The procedure for phosphorus fractionation was a modification of that developed in the field of soil science and consisted of extraction using 1.0 N NaOH and 1.0 N HCl. Iron and aluminum phosphate and adsorbed phosphorus were recovered in NaOH-extractable orthophosphate (NaOH-O-P) fraction, calcium phosphate in HCl extractable orthophosphate (HCl-O-P) fraction, and organic phosphorus in NaOH extractable total phosphorus except for orthophosphate fraction and residual fraction. The results showed that the NaOH-extractable orthophosphate (NaOH-O-P) fraction was the main constituent of sediment phosphorus, and that this fraction was the form most easily released under anaerobic conditions. From their studies the authors concluded that the potential for phosphorus release from sediments was closely related to the amount of the NaOH-O-P fraction present and was thus an index of the release potential.

Bruwer (South Africa), the invited discusser, stressed the practical importance of an understanding of the forms and quantities of phosphorus release from sediments in developing a rational program for management of lakes. It is possible that in some situations the contribution from internal sources, in a lake for example, may provide sufficient phosphorus to support growth and kept water quality down and raise questions as to the economic feasibility of removing phosphorus from external point sources. A key point, however, is to determine the fraction of phosphorus that is biologically available. It would be desirable to expand the study being conducted to include bioassay procedures relating phosphorus that is biologically available. It would be desirable to expand the study being conducted to include bioassay procedures relating phosphorus release to phosphorus utilization. Bruwer (South Africa) expressed concern about prolonged storage of samples at 4°C and referred to studies which showed that the NTA-extractable fraction doubled after a storage period of three to four months at 4°C. The authors responded that they stored samples for one month and elected not to freeze samples because such treatment would destroy the structure of the sediments. Bernhardt (Federal Republic of Germany) pointed out that the index was limited to release under anaerobic conditions but that release can also take place under aerobic conditions and extension of the studies to include aerobic release would be desirable. The authors agreed with the suggestion but pointed out that their studies indicated much higher concentrations of phosphate in the anaerobic interstitial water than in overlying aerobic water.

C. Paper No. 44: "The Influence of Sediment Water Interactions in an Impoundment on Downstream Water Quality," by T. J. Grizzard, C. W. Randall, and E. M. Jennelle (U.S.A.)

The general purpose of the research was to evaluate sediments as a source of plant nutrients. In addition, a specific investigation was made to determine the role of sediments in regulating phosphorus supply in the overlying water column and to assess the water quality impact of the presence of a small upstream impoundment on a large downstream reservoir. The reservoirs are located in southwestern Virginia and the upstream impoundment (Niagara Reservoir) received

11.4×10^4 m^3/d of secondary wastewater treatment plant effluents which contributes 64 percent of the phosphorus entering the basin. About one-half of the surface drainage entering the downstream reservoir (Smith Mountain Lake) must first pass through the Niagara Reservoir.

Sediment and water quality sampling stations were established in the Niagara Impoundment and analyzed to determine inorganic phosphorous fractions using modified Chang-Jackson extraction procedures. Laboratory studies on sediments were carried out in cylindrical reactors, 19 cm in diameter and 38 cm long. The reactors were provided with mixing equipment, air diffusers, and platinum electrodes for measuring electrode potential in the water column and in the sediment. The reactors were operated in the dark at 20°C and the studies were designed to assess the effects of the following on plant nutrient behavior: (1) surficial sediment constituency; (2) exposed surficial sediment area; (3) water column and sediment electrode potential; and (4) water column phosphorus concentration.

Seasonal changes in the character of the surficial sediments of the Niagara Impoundment were observed through the analysis of a time series of samples collected over a 15-month period. Al-P, Fe-P, and reductant-soluble sediment phosphorous declined during the summer months, indicating a release to the water column. At the same time, a dramatic decline in extractable iron of the sediment prompted the conclusion that the primary release mechanism was anaerobic destruction of insoluble ferric iron compounds followed by liberation of sorbed and precipitated phosphorus species. In the overlying water column, iron and phosphorus concentrations showed increases of 1.0 and 0.8 mg/ℓ, respectively, through a reach of the Niagara Impoundment during the summer and, conversely, concentrations were observed to decrease during the winter and spring. Aerobic-anaerobic reactor studies demonstrated that large quantities of phosphorus could be stored in surficial sediments when oxygenated and subsequently released during anoxic conditions. The active portion of the sediment-water interface was found to extend an average of only 2 mm into the sediment profile. The results showed that phosphorus exchange was essentially a surface phenomenon and that the net amount of phosphorus adsorbed decreased with decreasing surface area under aerobic conditions and that similarly regeneration under anaerobic conditions was decreased.

The authors concluded that the sediments of the Niagara Impoundment tend to redistribute the annual nutrient load entering the basin, raising the concentrations of phosphorus in the outflow during the critical growing period in the summer and thereby contributing to water quality degradation in Smith Mountain Lake. Effective reduction of phosphorus to the lake could be achieved by maintaining aerobic benthic conditions in the Niagara Impoundment.

Hattingh (South Africa), the invited discusser, stressed the importance of sediments to water quality in reservoirs. He pointed out that sediments can bind a large number of compounds including heavy metals and can transport these compounds over long distances to reservoirs. He referred to studies in South Africa which showed that about 80 percent of the total phosphorus in certain streams was bound to the sediments. He drew attention to the high level of phosphorus, 0.5 mg/ℓ, reported by the authors as present in the Niagara Impoundment attributable to the large volume of wastewater discharge. This limited the effectiveness of the upstream impoundment to store nutrients. In view of the fact that the impoundment is rather shallow, he inquired as to the extent of the resuspension of sediment that could result from mixing by wind action. Randall (U.S.A.) replied that there was mixing by the wind and that the high phosphorus content and anoxic conditions in the impoundment during summer were related to the large quality of wastewater inflow. Randall also stated that releasing effluent high in nitrate content is a control strategy that can be used in place of aeration in the reservoir. Arvin (Denmark) inquired as to the level of nitrate needed. Although specific data were not available, Randall (U.S.A.) was of the opinion that about 2 mg/ℓ of nitrate was a reasonable value.

Bernhardt (Federal Republic of Germany) stated that experience in Germany showed that impoundments used to trap sediment before principal reservoirs were effective and that Ullman and Bendorf have developed with success a system of building upstream impoundments to retain nutrients. Imhoff (Federal Republic of Germany) supported these comments. It was generally agreed that the nature of the sediments and the extent and time of year at which inert sediments may enter the impoundment and amount of organic and inorganic phosphorus present, as well as electrode potential values in sediment, would have to be considered in particular situations. The adverse effects of the upper impoundment on water quality in the lower reservoir as reported by Randall (U.S.A.) were likely the result of the large inflow of sewage effluent.

D. Paper No. 46: "River Basin Planning for Control of Nitrate Pollution," by C. S. Sinnott and D. G. Jamieson (United Kingdom)

This paper reported the work of the Thames River Authority aimed at assessing the impact that water quality in general, and nitrates in particular, have on management and performance of the Thames water resource system. The Thames basin supports a population of approximately 11.5 million and covers an area of about 13,000 km^3. The Authority and its agents provide potable water at a rate of 3.3 x10^6 m^3/d. An additional 1.4 x10^6 m^3/d is licensed for direct withdrawal. About 58 percent is met by surface water and 42 percent taken directly from underground supply.

A recent European Economic Community (EEC) Directive on water quality standards establishes the maximum permissible concentration of NO_3-N in potable water at 11.3 mg/ℓ. Nitrate levels in the Thames River and its tributaries have been slowly increasing for many years. Of particular concern was the fact that over the past decade there has been a marked upsurge in the rate of increase. For example, at the Walton Intake, the main source of supply for London, the average annual concentration of nitrate-nitrogen has risen from 4.2 mg/ℓ to 7.7 mg/ℓ between 1968 and 1979. In addition, seasonal fluctuations commonly cause short-term concentrations to be 2 or 3 mg/ℓ above the annual mean.

The combination of increasing nitrate concentrations and the recent EEC directive is posing a potential problem to the Thames Water Authority and has given impetus to the development of a program to formulate a planning methodology and definition of the optimal development strategy using analytical techniques previously developed for water quantity. Time-series analysis was used to relate the total nitrate input with the corresponding flow-weighted average annual nitrate concentration at the Walton intake. A model was developed and predictions for different scenarios including the factors of population growth rates and farming practices indicated that for the year 2000 predictions of average annual nitrate concentrations in the lower Thames ranged from 9.8 mg/ℓ to 15.5 mg/ℓ.

The planning methodology that has been developed is a large-scale simulation, and is essentially an extension of the approach adopted for the quantity aspects of water resources planning. Five basic component models have been identified: (a) soils subsystem, (b) aquifer subsystem, (c) channels subsystem, (d) reservoirs subsystem, and (e) treatment subsystem. The model formulation, parameter estimation, and model validation phases have been completed. Evaluation of alternative strategies to overcome nitrate-related problems is now underway. It was indicated that in view of the substantial amounts of money for capital investment and operating costs to control nitrate concentrations, there is need for a more realistic basis "for determining a tolerable level of nitrates in potable water."

Preul (U.S.A.), the invited discusser, stated that in the United States the maximum contaminant level for nitrates has been established by the U. S. Environmental Protection Agency (EPA) at 10 mg-N/ℓ, and this value is based on health effects in infants and that adults can be exposed to much larger concentrations. Consideration is being given to changes in the value of 10 mg N/ℓ but nothing definite has been done as yet. Past concern in the United States has been with well waters but recent data indicate a trend of increasing values in river waters. Preul (U.S.A.) emphasized the need for careful nitrogen balances in a watershed and improvement in fertilization practices.

Vivier (South Africa) stated that if the limit for nitrate nitrogen was based on health effects in infants, it might be more cost effective to provide a separate supply of bottled water for children. In response to his question as to how to deal with denitrification in rivers, Sinnott (United Kingdom) stated that this was allowed for because the model related the nitrogen input to the measure of nitrogen at the downstream end.

IV. CRITIQUE OF SESSION

The four papers in this session were concerned with river and lake water quality. Two papers (Nos. 42 and 44) were directly related and dealt with questions of forms of phosphorus in sediments as related to release. These two papers were in substantial agreement that the NaOH extractable orthophosphate (NaOH-O-P) fraction (i.e., iron and aluminum phosphates) was the main constituent of sediment phosphorus, and that under anaerobic conditions the bulk of the release was from iron-bound phosphates.

Both papers confirmed the validity of the phosphorus fractionation method, developed by Chang and Jackson in the field of soil science, in providing quantitative information on lake and stream sediments. Detailed information was provided in both papers on sediment samples obtained from field locations receiving substantial loads of phosphorus and other nutrients from sewage treatment plant effluents. Although the results from the fractionation techniques provided valuable information on the forms of phosphorus present and released to the water column, additional research to determine the fraction of phosphorus that is biologically available is warranted.

There was considerable difference of opinion regarding the effectiveness of an impoundment to trap sediments before the principal reservoir. Randall (U.S.A.) concluded unless aerobic conditions are maintained in the upstream impoundment, release of nutrients from previously deposited sediments would and did provide a continuing source of phosphorus to the outflow during critical summer months and contributed to water quality degradation in the downstream reservoir. It was likely that this finding resulted from the large inflow of sewage effluent to the upstream impoundment and that the impoundment was acting as a treatment lagoon. Experience in Germany has been the upstream facilities have had a beneficial effect on the principal reservoir.

Paper No. 40, which reported the impact of nuclear power plants on the River Meuse, was indeed a valuable contribution.

The report, covering five years of investigation, was comprehensive and detailed. The data analysis provided a sound basis for prediction of the impact of additional nuclear power development on river water quality.

Paper No. 46 was an excellent presentation of the large-scale detailed model formulation for comprehensive water resource planning and management undertaken by the Thames River Authority. The development of five basic component models and their linkage provided a means to evaluate alternative strategies to meet requirements for nitrate concentrations in water supplies. Although there has been a large investment in the study, this appears to be justified in light of the magnitude of expenditures that may be needed to control nitrate levels. Both the authors and discussers expressed the need for more definitive evidence regarding health effects of nitrates in potable water and economic impact to meet prescribed values.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Although dealing with different pollutants, the large-scale modeling studies for prediction of impact of pollutants on water quality in rivers provide excellent examples of the increasing application of this approach to water resource planning and management on a large river basic scale. The Thames River approach might prove of particular interest in connection with the current requirement by the EPA to establish water quality criteria for toxic pollutants. In those locations where toxic pollutants need to be controlled, models to evaluate the options available will be valuable in making decisions on a regional basis. As the pollution control problem grows, the technical, socio-economic, and legal problems become more complex and systematic planning through the use of simulation modeling and optimization techniques will be required to implement a rational and orderly program to approach optimum use of the resource. A detailed review of the Thames River Authority model should be made.

The papers on phosphorus release provide additional and confirmatory information on the significance of the sediment as an internal source and the necessity to carefully evaluate this source in the nutrient budget of lakes and reservoirs. The analytical techniques to determine fractional composition of phosphorus forms appear to be well established, but additional research on evaluation of fractions that are biologically available is warranted.

I. SESSION

A. Day: Friday, April 2, 1982
Hall: A
Time: 9:00 a.m. to 12:35 p.m.

B. Theme of Session: Concentration Techniques for Viruses in Water

II. REVIEWER

A. Name: Ronald D. Neufeld

B. Position and Affiliation: Associate Professor of
Civil Engineering
Environmental Engineering
Program
University of Pittsburgh
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III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 48: "Virus Removal by Filtration," by N. Sriramulu and M. Chaudhuri (India)

This study deals with the utilization of filtration as a means for virus removal. A "model enterovirus," the MS-2 phage of *E. Coli*, was utilized in this study which was designed to provide process information for virus removal that may be useful to the drinking water industry. A column (2.5 cm ID) with 0.5 mm sand was used for filtration experiments. A groundwater with no initial turbidity was used in all experimentation. Kaolinite was added to the groundwater to provide artificial levels of turbidity; turbidity was removed from the kaolinite-spiked groundwater sample via coagulation with alum, with and without use of a polyelectrolyte (Purifloc C-41). Phage concentration of waters ranged in concentration from 4.6×10^3 to 7.3×10^3 PFU/mℓ. The sand media was also treated as needed with alum, or alum and Purifloc C-41. Removal of suspended solids through the column was found to be first order throughout the 45 cm depth of the sand column.

Results utilizing virgin sand and water with and without turbidity showed a 22.6% virus removal in clear water, and a 72.9% virus removal when influent water with turbidity was utilized. In this latter experiment, 97.4% of the total turbidity was removed. The authors concluded that fine turbidity particles act as carriers of the virus, explaining that when turbidity particles are removed by the sand filter, the viruses are similarly removed.

However, due to the fact that the percent removal of virus (72.9%) was less than the percent turbidity removal (97.4%), it was also concluded that a small fraction of viruses were not sorbed onto turbidity particles. In the case of alum-coagulated waters, overall virus removal was increased to 98.3%, and the overall virus removal was increased to 99.8%. Apparently, the process of coagulation aided in overall virus removal due presumably to the sorption of viruses to coagulated turbidity particles or to aqueous alumina complexes.

Sand pretreated with either alum or Purifloc increased virus removal efficiencies. The authors conclude that while turbidity removal is due to particulate impaction and settling in deep-bed filters, virus removal in the absence of turbidity is due, in fact, to electrokinetic phenomena and interaction with sand surfaces. When viruses are in water with turbidity, viruses tend to adsorb on to turbidity particles. Since the turbidity particles become carriers of the viruses, the virus removal mechanism is thus identical to that of the turbidity particle removal mechanism in deep-bed filters.

For waters containing zero turbidity, virus removal is enhanced by pretreating the sand with alum. This will modify zeta potentials in the neighborhood of the sand particles and cause electrokinetic capture of virus particles. For normal surface waters where turbidity is present, the best virus removal is achieved by alum coagulation of turbidity particles followed by deep-bed filtration with sand also pretreated with alum.

In the assigned discussion, Leong (U.S.A.) noted that few experimenters are using deep-bed filter processes for virus removal. He commented that studies such as this would be greatly improved with more data and incorporation of statistics for a better evaluation of the precision results. Statistical evaluations would lend a greater credibitility to the premise put forth by the authors that coagulation and alum-treated sand are useful for virus removal in deep filtration beds. In addition, the author's allegation that virus removal was achieved via an electrokinetic phenomena has not been conclusively demonstrated. Further information is needed to elucidate the mechanisms involved in virus removal in low- to zero-turbidity water.

In the floor discussion, Nupen (South Africa) indicated that the model enteric virus utilized may not, in fact, have been typical of all enteric viruses. It was their experience that many rotoviruses and other enteric viruses have zeta potentials close to zero. Accordingly, while alum-treated sand may removed the MS-2 "model" virus used by the authors, it is questionable whether the treated sand is similarly effective for all enteric viruses. In addition, since filter runs were only six hours long, questions were raised as to the ability of deep bed filters to remove viruses over a typical 24-hour filter run. Further questions were raised as to the alum retreatment of the sand after each backwash.

Bernhardt (Federal Republic of Germany) commented that the reported experiments were valuable first-step approaches towards process design. In this case, the authors should have sought to minimize wall effects by utilizing columns with diameters perhaps as large as 20 to 30 cm. In addition, it is not yet possible to verify a linkage between turbidity removal and virus removal from all types of waters. Additional experimentation is required on a world-wide basis with a variety of surface waters to provide data illustrating that such a linkage conclusively exists. Thus, not only are additional experiments necessary to prove the linkage between turbidity removal and virus removal, but improvements are necessary in the virus enumeration procedures to assure statistical validity.

Belfort (U.S.A.) commented that in a real system, with a distribution of virus sizes, and a distribution of sizes of turbidity particles, the mechanism for capture and attachment is quite different. With small turbidity particles, the capture efficiency for viruses may be much greater than when larger particle sizes are utilized. Accordingly, this study is specific for the one virus, one flow rate, and one grain size of particle utilized. Extrapolation of these results to other systems should not be done at this time.

Sproul (U.S.A.) mentioned that previous (unpublished) dissertation data showed that as sand particles are made smaller, increased removal efficiencies of viruses are obtained in the bed filtration. For sand particles of greater than 35 mesh size, minor virus removals take place. As the sand grain size decreased down to 72 mesh, increased efficiencies in virus removal were noted. As the ionic concentration of the water increased, increased virus removals were noted. In addition, as the concentration of divalent ions increased (as compared to monovalent ions), virus removal also increased. It was further noted that much information available in doctoral dissertations have yet to be utilized by environmental researchers and practitioners.

B. Paper No. 50: "Enterovirus Concentration Using Automated Hollow Fiber Ultrafiltration," by G. Belfort, A. Paluszek and L. Sturman (U.S.A.)

Data were presented which showed how a small hollow-fiber ultrafiltration system, as used in hospitals, may be used in an automated mode for the concentration of viruses from tap and drinking waters. The automation technique developed by the Amicon

Corporation (U.S.A.), was further improved under their sponsorship by the authors. Polysulfone membranes of the order of about 250 μm were successfully used to separate viruses from tap water. No virus was found to exist in the permeate stream. An existing system was modified with pressure gauges for automated backwashing use. Poliovirus-2, echovirus-1 and reovirus-1 were utilized in the study. Initial experimentation found that the viruses were attached to the membrane and were not recovered when permeate alone was used for backwashing. The solution concentration of the backwash was modified by incorporation of pH buffers and glycine in solution to enhance virus recovery. Poliovirus recoveries were enhanced at pH values in the range of 9 to 10, while echovirus and reovirus recovery efficiencies did not appear to be a function of backwash or pH in the range of 5.0 to 10.0. One disadvantage in using this technique, as in all virus concentration techniques, was that a parallel concentration of cytotoxic and trace organic materials may also occur.

The hollow fiber technique was used with feed concentrations ranging from 4.3 PFU/mℓ to 1.1 x 10^6 PFU/mℓ of enteroviruses with feed volumes of 3 to 100 ℓ. Concentration factors of 2 to 215 times were achieved and recoveries ranging from 79% to over 100% were found. The major advantage of this technique was the automated capability which was expected to result in a labor savings over the complicated procedures associated with the existing "Tentative Standard Method" (TSM) for virus recoveries from water.

In his prepared discussion, Sproul (U.S.A.) confirmed the inherent advantage of using an automated virus concentration recovery technique. One disadvantage for the technique, however, is that recoveries are not complete and viruses tend to stick to the membrane. This disadvantage becomes apparent if the technique becomes adopted for regulatory purposes where one needs an assurance that the virus is recovered clearly from the sample utilized. Unless the membrane is removed from the system and changed prior to each virus determination, no such assurances can be made.

The authors indicated that "cell associated viruses" were utilized, i.e., were still associated with cell membranes and the overall particle size of this complex may be on the order of 10 μm, a size in excess of that expected of discrete viruses in tap or drinking waters.

Sproul (U.S.A.) raised questions of the engineering feasibility of a system equipped to sample thousands of liters of tap water. He pointed out that if a virus standard on the order of one per thousand liters were, in fact, promulgated, 31 samples, each of a 1,000-liter size, would be required to be certain that the standards were met with a 99% confidence level. If an 80%

confidence level were acceptable, the requirements for sampling would be reduced to 4,000 liters. In this analysis, it was assumed that there was a 100% recovery of viruses from each sample, an achievement which has not as yet been reached by any concentration technique to date. In addition, a technological limitation in concentrating large sample volumes would be the limitations imposed by small levels of turbidity, organic substances and cytotoxic substances.

In response, Belfort (U.S.A.) indicated that disinfection of membranes between each run can be readily achieved via the use of diluted sodium hydroxide on the polysulfone membranes. The problem of sorption of viruses on the polysulfone membrane is an inherent difficulty with the technique. Research is under way to examine alternative hydrophillic membranes, such as regenerated cellulose acetate membranes and polyamide membranes, as a compromise between the hydrophobic polysulfone membrane and the hydrophillic membranes currently available in the marketplace.

Nupen (South Africa) routinely concentrates water for virus evaluations by factors of about 100. The requirements of their experimental procedures are to establish a final volume of approximately 90 mℓ, and any device that could provide such small final volumes with increased concentration factors over one hundred times are welcome. A second point raised was the need to be absolutely sure that if viruses are found in a sample, they were derived from the original water sample tested. Because of this requirement, the South African practice is to carefully sterilize the total apparatus with great care. Nupen (South Africa) noted that for an automated system to be practical, not only must the membrane be sterilized after each run, but also peripheral pumps, tubes, and valves must similarly be sterilized.

C. Paper No. 52: "A Comparative Study of Methods for Concentration of Human Enteroviruses," by M. Martins, E. Marques and L. Soares (Brazil)

Martins (Brazil) reported on a study to determine suitable laboratory techniques for the isolation of viruses in sewage samples from Sao Paulo, Brazil. The techniques utilized were: adsorption on aluminum hydroxide floc, precipitation by aluminum sulfate, adsorption to and elution from membrane filters followed by organic flocculation, direct organic flocculation as a single-step concentration method, and electropositive cartridge filter (AMF Cuno filter). The results indicated that the greatest number of recovered plaque-forming units came from adsorption on aluminum hydroxide.

The prepared discussion by Nupen (South Africa) highlighted the importance of conducting studies aimed at determining the type of virus and numbers of types of each virus in sewage samples. For this study, three polio viruses, five echoviruses, and four coxsackie viruses were specifically isolated. Nupen (South Africa) raised questions on the desirability of using the BS-C-1 cell culture technique for enumeration of both slow-growing and rapidly-growing enteroviruses. The culture media these authors used favor the growth of rapidly-growing viruses, such as of the types reported, and would effectively mask the presence of any of the slower-growing virus varieties. She further commented that the paper illustrated typical problems associated with poorly funded viral research in that, to accomplish the goals of identification of slower-growing viruses, multiple samples as well as multiple cell-culture techniques should be employed, and for completeness, an epidemiological study should have been conducted as to disease patterns before, during and after the viral investigation.

Guttman-Bass (Israel) requested information on overall virus loss during the filtration and centrifugation phases of virus concentration. The authors replied that virus recovery efficiencies at various points within the technique were not part of this scope of study.

Grabow (South Africa) commented that with the high levels of E. *Coli* in the samples, the expected virus concentration should, in fact, be much higher than shown. He was surprised that no rheoviruses were measured. He commented that it was possible that rheoviruses were not observed due to the nature of the host cell culture system utilized, and urged that a variety of host cell systems be utilized in such virology research.

D. Paper No. 54: "A New Large Scale Technic for Quantitative Recovery of Enteroviruses by Adsorption on Suspended Glass Powder. Application to Surface and Drinking Waters of the Paris Area," by P. Vilagines, D. Sarrest, C. Danglot, and R. Vilagines (France)

The purpose of this research was to describe a new and economical method for the concentration of viruses from drinking waters and surface waters. The procedure employed was to use small glass particles with a natural negative electrical charge for sorption of enteroviruses with a positive charge. The motivation in conducting this research was to (a) minimize the costs of filters ordinarily used during standard concentration procedures and, (b) minimize clogging of filters which operators face when attempting to concentrate viruses. The procedures are as follows: Approximately 2 kg of sterile glass powder with diameter size of about 100 to 200 μm are placed in a plastic cone; water, which is acidified to pH of 3.5, is allowed to flow in the cone; viruses which are sorbed onto the glass beads are subsequently removed via an elution using a glycine buffer system at pH of 11.5; the elutent is inoculated into cell culture systems. Virus recoveries on the order of 30% to 41% were found with lower efficiencies coming from river waters and higher efficiencies from drinking waters. Such recoveries may be suitable and, in fact, expected due to inherent errors associated with bioassay monitoring of such living systems.

Roy (U.S.A.) noted that apparatus complexity was, in fact, on the order of the hollow fiber system [previously reported by Belfort (U.S.A.)]. He noted that the developers of this technique did not provide information regarding the influence of turbidity and organic materials on virus recovery rates. In addition, using the apparatus described, substantial variations occurred when comparing the results of a single 500-ℓ sample analyzed for viruses versus a comparable number of 10-ℓ samples. It was not apparent that the 10-ℓ samples came from the same water source as did the larger 500-ℓ sample.

In the floor discussion, Hartemann (France) commented that percent recoveries are usually evaluated with water samples that are spiked with a known virus. The percent recoveries of indigenous viruses in a surface water source may be considerably less. In addition, he noted that the glass-bead technique is probably more suitable for sampling of small quantities of sewage samples because of the advantage of lack of clogging; however, the conventional filter technique is to be preferred when looking at high-volume drinking water samples.

Grabow (South Africa) noted that this and other techniques that utilize high pH values for virus elution tend to destroy certain types of enteroviruses. For example, most Echo and Rheo-type viruses will be totally destroyed at high pH values leaving only the polio virus and other hardy virus types for subsequent cell inoculations. Thus, this technique, as well as many others, have serious shortcomings in that they cannot provide information on large numbers of different virus types. In addition, Belfort (U.S.A.) commented that at pH levels of about 11.5, portions of the glass beads may be expected to dissolve thus again leading to questionable results.

IV. CRITIQUE OF SESSION

Research in the field of virus removal appears to be at an elementary level where reliable measurement techniques are still to be developed.

Paper No. 48 dealt with a fundamental evaluation of removal of viruses in deep-bed filtration systems. Questions were raised regarding the experimental procedures utilized and application to large-scale systems. However, it was commented by many that this was perhaps one of the first approachs associated with developing process-type experiments which have applicability to the drinking water industry.

Remaining papers were focused on techniques associated with concentration of viruses from surface waters, drinking waters and sewage samples. These papers would have great appeal to analytical laboratories involved with the routine determination of viruses in such waters. Apparently, analytical problems and manipulative problems exist with the virus concentration method outlined in *Standard Methods*. These papers represent alternatives to the standard method. It should be noted that concentration methods are only a portion of the problem and, as pointed out in floor discussion, serious errors similarly result in the elution method (which tend to destroy some viruses) and in the cell inoculation method (which may tend to favor the growth of some viruses over others).

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

It is clear that waterborne viruses can cause distress to water consumers. Accordingly, methods for the detection of virus and for the treatment of viruses in surface waters should be developed. No epidemiological data, however, have been developed to quantify the risk of disease from virus contaminated waters, or to assess the relative risk and importance of the "virus problem" as compared to other problems (such as PAH's) in drinking water and wastewater treatment systems.

If regulations are to be developed regarding virus concentrations in waters, it is clear that further research and development in techniques associated with monitoring and treatment will be necessary. Technological limitations appear to exist in the area of concentration and recovery of viruses, particularly those viruses of a less hardy type. While, for example, polio virus may survive the concentration procedures employed, it is not clear the polio virus should be used as a "surrogate" for viruses which commonly are shown to cause disease in water consumers.

Perhaps a more fruitful approach to setting a virus standard is to set a technological-based standard for the operation of drinking water facilities. As shown in Paper No. 48, it is possible to modify off-the-shelf technologies in the drinking water industry for the removal of viruses. Further research is required to resolve questions of time of filter run, sand size and effects of backwashing. Analytical techniques must be developed to support this line of research.

If virus standards are to be promulgated in the United States, consideration should be given to the development of regional laboratory facilities for cell culture inoculations. A simple but standardized virus concentration procedure should be developed for use by operators of local drinking water and wastewater treatment facilities. Regional laboratories utilizing the more expensive and sophisticated cell inoculation procedures, may be effectively employed to provide uniformity and quality control over viral analysis.

I. SESSION

A. Day: Friday, April 2, 1982
Hall: A
Time: 2:00 to 5:30 p.m.

B. Theme of Session: Disinfection; Surface Water Quality

II. REVIEWER

A. Name: Joseph P. Gould

B. Position and Affiliation: Research Scientist
School of Civil Engineering
Georgia Institute of Technology
Atlanta, GA

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 56: "Ozone as a Sterilising Agent, Its Advantages and Disadvantages in the Treatment of Water," by M. Schalekamp (Switzerland)

The results of laboratory studies and experience garnered during 30 years of the use of ozone as a disinfectant in Switzerland were presented. Ozone dosages of 0.5 mg/ℓ or more were sufficient to totally eliminate all coliform organisms in water. It was found, however, that ozonated water was subject to a substantial regrowth of bacteria on standing for three weeks or more. This regrowth was strongly retarded if 1 mg/ℓ of chlorine was used in addition to 5 mg/ℓ of ozone. In this case, regrowth did not begin until six weeks had passed. The author ascribed this regrowth to the generation of aldehydes and ketones resulting from the action of the ozone. He theorized that these carbonyls were being used by the bacteria as a carbon source thereby stimulating their regrowth. The correlation between the levels of aldehydes and ketones in the water and the ozone dosage was clearly documented. The impact of rapid and slow filtration and activated carbon filtration on this phenomenon was demonstrated by means of gas chromatography.

Studies on bacterial and viral inactivation by ozone demonstrated that, in the absence of excessively high levels of raw water contamination, ozone dosages in excess of 1.0 to 1.5 mg/ℓ would not be necessary. Furthermore, these dosages of ozone would minimize the generation of aldehydes and ketones.

Ozone was found to contribute substantially to the reduction of the concentration of such undesirable compounds as phenol and trichlorophenol and to reduce markedly the generation of trihalomethanes on subsequent chlorination of the water, with 50 to 75% reductions being realized. Ozone was also found to have a beneficial effect on such gross measures of organic contamination as COD, color and ultraviolet adsorption. Again, care was urged in minimizing the dosages of ozone due both to the carbonyl generation phenomenon and the fact the excessive dosages of ozone were found to have a negative impact on flocculation.

The monitoring of ozone in water and air was discussed. It was pointed out that ozone is a substantial air pollutant and that its levels in effluent gases from the ozonation process should be kept at minimal levels by appropriate treatment techniques. The use of simple dilution techniques for small plants was described while larger operations were found to be best served by means of thermal or catalytic processes or by a combined thermal-catalytic technique. The latter process was found sufficient to reduce ozone levels in air from more than 3,000 mg/ℓ to below detection limits at very modest costs.

van Leeuwen (South Africa) speculated that regrowth after ozonation might be due to acids generated by oxidation of the aldehydes produced. He also observed that ozone is not a perfect disinfectant since many bacteria such as P. *aeruginosa* are resistant. The author responded that, while ozone is indeed not perfect, as a rule viruses and coliforms are inactivated by ozone and resistant organisms tend to be relatively harmless strains. Ozone is especially effective, relative to chlorine, against viruses.

Pretorius (South Africa) asked about the impact of ozone on flocculation. The author responded that preozonation to levels of approximately 1.5 mg/ℓ markedly improved flocculation. However, ozonation to 3 to 5 mg/ℓ tended to reverse the gains realized at the lower dosages of ozone.

A request by Masschlein for additional data on the bacterial regrowth curves elicited the response that regermination will occur only if the ultraviolet absorbance exceeded 0.5 units.

B. Paper No. 58: "The Mechanism of Ozone Inactivation of Water Borne Viruses," by O. J. Sproul, R. M. Pfister, and C. K. Kim (U.S.A.)

The inactivation of the bacteriophage T4 by ozone was reported in this paper. The results of these studies were compared with previously reported research on f2 phage. Ozone was found to reduce T4 phage by seven log-units as measured by the plaque forming unit (PFU) technique in 120 s at ozone dosages of 0.2 to 0.5 mg/ℓ. The ozone caused a very rapid destruction of the structural integrity of the phage. The tail sheaths had contracted, DNA and base plates were lost and head and DNA destruction had occurred. Electron microscopy showed conclusively that rapid fragmentation of released DNA took place with complete fragmentation within 120 seconds.

Some evidence regarding the mechanism of viral inactivation was presented. Indications were that DNA released from the T4 phage was rapidly inactivated by ozone. DNA inactivation occurred at the same rate as that of the phage itself. This contrasted with findings obtained with the f2 phage in which nucleic acids were at least partially inactivated within the capsid sheath. Indeed, RNA from the f2 phage was inactivated more rapidly within the capsid sheath than as the naked RNA. In the case of the T4 phage, ozone inactivation occurred by loss of the capsid structure and release and inactivation of nucleic acid. In addition, ozone was found to inhibit the attachment of the virus to the host cell. RNA inactivation was found to proceed more slowly than DNA inactivation.

A question was asked regarding the nonlinearity of the disinfection kinetic curves. Sproul (U.S.A.) responded that this nonlinearity was not uncommon and was likely a result of increased inherent resistance of long-term survivors to the disinfectant.

The author indicated uncertainty concerning the mechanism by which the RNA was inactivation within the capsid. Grabow (South Africa) suggested that tight packing of RNA and DNA within the capsid renders them more sensitive and vulnerable to external disturbances. He reported that similar results have been obtained in the case of ammonia inactivation of viral nucleic acids. In essence it seemed that the capsid was not primarily a protective mechanism.

In response to a question from the chair regarding ClO_2 mechanisms, the author indicated that the mechanism of ClO_2 inactivation of virus remains largely unelucidated. Sproul (U.S.A.) indicated, while a fair amount of information is available on ultraviolet inactivation of microorganisms and on the mechanisms of HOCl disinfection, few data are available on other disinfectants. Also lacking is information on the inactivation of higher organisms such as parasites and cysts.

B. Paper No. 60: "Predicted Changes in Water Quality After Elimination of Storm Runoff into the Urban Lakes and Canals of Hamburg," by H. Caspers (Federal Republic of Germany)

Application of a water quality model to predicton of the impact of elimination of combined sewer overflow on the quality of an urban lake was reported. Alster Lake, a small shallow impoundment is entirely surrounded by the City of Hamburg. During heavy rainfall, the impoundment receives substantial overflows from the combined sewer system. This has led to rapidly increasing eutrophication in this lake leading to local depletion of dissolved oxygen, occasional fish kills and blooms of algae. Methane and hydrogen sulfide are produced continuously. Construction projects presently planned or underway are directed toward improvement of the sewer system and consequent reduction of the overflow of wastewater into the lake. The paper reported on an effort of predicting the impact of these projects on the quality of Lake Alster.

Studies in Swedish Lakes have indicated that restoration of hypertrophic lakes cannot be achieved by termination of nutrient input alone. Removal of nutrient-rich sediments is also necessary. A brief analysis of the application of this finding to the Alster situation indicated that such methods as iron and aluminum precipitation of phosphates, *in situ* sediment oxidation by nitrate addition and covering of the sediment layer by fly ash would not be suitable for treatment of Alster Lake.

A seven-stage chemical water quality index, based on eight chemical parameters, was used to assess the present status of Alster Lake and to predict the impact of various strategies on the saprobic state of the lake. The applicability of the water quality index chosen was tested by the application of the index to water quality changes resulting from the termination of sewage flow into a Hamburg canal. The index successfully paralleled the changes in quality of the canal. Application of the index to Alster Lake indicated that a 50% reduction in nutrient flow to the lake would result in a significant improvement in lake quality while 90% nutrient removal would produce a year-round balanced mesosaprobic state in the lake. Annual curves showing changes in the water quality index for the Eilbek Canal and the predicted changes in the Alster Lake were given.

The discusser on this paper raised several questions relative to the use of Water Quality Indices (WQIs) in general and the particular index presented. He commented that WQIs have been largely unsatisfactory and expressed difficulty with the use of single number indices which are oversimplified and lead to numerous errors. The use of orthophosphate rather than total soluble phosphorus, which was indicated as being a more reliable measure of available phosphorus was questioned. He questioned the use of conductivity in this system and asked if fewer than eight parameters might be used to measure changes in the WQI. He inquired if this WQI, which was developed for Scottish rivers, could be applied to the Alster Canal. Finally, he asked what factors tended to keep the predicted index fairly high, even following removal of 90% of nutrient transport to the canal. The author responded that he was initially skeptical of the value of the WQI, but was impressed by its ability to describe adequately the current conditions and to predict changes in real systems. He did agree that the various parameters will have to be modified in the future to fit specific situations. He also agreed that total soluble phosphorus would be preferable to orthophosphate in the index but used the latter because it was all that was available.

D. Paper No. 62: "Quality and Quantity of Stormwater Runoff from a Commercial Land-Use Catchment in Natal, South Africa," by D. E. Simpson and P. H. Kemp (South Africa)

This paper was an examination of the annual import of nitrogen, phosphorus, COD, BOD and heavy metals by atmospheric deposition and export of the same by runoff. The study was conducted over a two-year period in an urban catchment of 12 ha., of which 9 ha. were classified as impervious. During this period, atmospheric fallout was collected and rainfall and stormwater flows measured. Flow-composited stormwater samples were collected for analysis.

The results were subjected to statistical examination and numerous conclusions were presented. There was only a weak relationship between rainfall and atmospheric deposition of suspended solids and total and soluble phosphorus. There was a stronger correlation between rainfall and the import of nitrogen, which was ascribed to transport of ammonia and nitrogen oxides in rainfall.

Runoff concentrations of most materials measured started at high levels, decreased rapidly as easily mobilized substances washed out, increased to a second peak and finally decreased to low baseline levels. Strong correlations were found for the concentrations of suspended phosphorus, nitrogen, COD and all heavy metals, except zinc, with suspended solids as the independent variable. Other strong positive correlations were between total COD and total BOD, suspended phosphorus and suspended nitrogen and total phosphorus and total nitrogen. Regression analysis for load-runoff relationships indicated the existence of strong positive correlations between runoff and total loads of suspended solids, nitrogen, phosphorus and COD.

With the exception of soluble nitrogen, atmospheric deposition accounted for well under half (e.g., 15-30%) of materials transported in runoff. In the case of soluble nitrogen, virtually all of the stormwater transport could be accounted for by atmospheric deposition. The stormwater management model (SWMM) of Huber and co-workers was applied to data obtained in this study. It was found that SWMM produced excellent predicted hydrographs but that failed to predict the transport of pollutants in stormwater.

The discusser endorsed the majority of the findings and commended the authors on a well-designed study. He suggested that a study of rural versus urban runoff in this manner would be of interest. He inquired about the use of only a portion of the total rainfall in the study and inquired concerning the impact of dry periods of various lengths. He also suggested that the anomalous first-flush behavior of phosphorus may have resulted from sorption of the phosphorus on solids. The author agreed with comments regarding the sorption of phosphorus. He also indicated that the rainfall shortage was due to equipment failure.

Barnwell (U.S.A.) indicated that failure of the stormwater management model was not a surprise. Similar problems had been encountered in the United States and such failures seemed unavoidable in a model as empirical as this one. He advised the authors of a newer version of the model which includes atmospheric deposition rates.

The author indicated that they were currently assessing the new model and expected it to help markedly. He also described steps taken to modify the older model empirically. This effort seems to have yielded a substantial improvement in the agreement of the model with field observations.

IV. CRITIQUE OF SESSION

The paper by Schalekamp (No. 56), while providing experimental research results, was oriented toward practial aspects of the application of ozone as the primary water disinfectant. The paper provided a wealth of operational detail and some substantial recommendations in the area of ozonation for water disinfection. Paper No. 58 also dealt with ozone disinfection but presented results of sophisticated laboratory research into ozone disinfection mechanisms with particular reference to viral inactivation. While direct practical applications of the results of this research are limited, the contribution of this paper to understanding of the disinfection mechanism was substantial.

The other papers (Nos. 60 and 62) dealt broadly with water quality considerations in the normal aquatic environment. Caspers (Federal Republic of Germany) examined the use of a water quality index in predicting the impact on a lake of the elimination of stormwater overflow from combined sewers. The paper was useful in drawing attention to both the issue and the inadequacies of existing water quality indices in either quantifying existing water quality or predicting the impact of changes on quality.

Simpson and Kemp (South Africa) evaluated the impact of stormwater runoff and atmospheric fallout on the transport of potentially detrimental materials into surface waters. An impressive feature of the paper was the extensive statistical analysis performed on the data collected. This analysis enabled the authors to assess the significance of various interrelationships in the runoff and fallout.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Paper No. 56. The findings of this paper pointed out the need to continue research into the impact of ozonation on general water quality. The finding that regrowth of bacteria can be stimulated by nutrients resulting from ozonation of non-degradable organic compounds emphasized the types of pitfalls facing researchers into any of the alternatives to chlorine. The generation of low molecular weight carbonyl compounds on ozonation of water-bourne organics also suggested that undesirable products may arise if such a water is then chlorinated. Research into such phenomena is necessary.

Paper No. 58. This paper continued investigations into the mechanism of disinfection. The clear implication of this paper for water pollution research in the United States is that the understanding of disinfection processes remains utterly inadequate to permit disinfection in the most accurate and economical manner possible with minimal use of potentially hazardous disinfectants.

Paper No. 60. Perhaps the most important indication from this paper was the need of further developing, testing and refining comprehensive water quality indices. While the index used did provide some approximations of the actual behavior of the water bodies studied, it was obvious that more refinement is needed.

Paper No. 62. This paper demonstrated the need for continuing research into the importation of pollutants by atmospheric fallout and stormwater runoff to surface waters. In addition, by documenting the total failure of a sophisticated hydrologic model to predict runoff transport of pollutants, a distinct gap in our modeling methods has been emphasized. Research toward eliminating this gap is required.

I. SESSION

A. Day: Monday, March 29, 1982
Hall: B
Time: 11:45 a.m. to 12:30 p.m.; 2:00 to 5:30 p.m.

B. Theme of Session: Biological Waste Treatment, Sludge Incineration and Rheology

II. REVIEWER

A. Name: William C. Boyle

B. Position and Affiliation: Professor, Civil and
Environmental Engineering
The University of Wisconsin
Madison, WI

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 2: "The Effect of Aeration Basin Configuration on Activated Sludge Bulking at Low Organic Loading," by S. E. Lee, B. L. Koopman, D. Jenkins, and R. F. Lewis (U.S.A.)

Over the past eight to 10 years, a substantial research effort has been devoted to the evaluation of the influence of reactor basin configuration and method of feed on activated sludge bulking control. Continuous-flow laboratory-scale studies were conducted to evaluate the effect of aeration basin configuration on low organic loaded systems typical of plants designed to achieve nitrification. Initially, the authors were unable to achieve a bulking condition at a range of F/M loadings of 0.05 to 0.25 g COD removed/g MLVSS using weak domestic wastewater. This weak wastewater was supplemented by blending with primary sludge to increase the COD concentration to 750 mg/ℓ. Thereafter, bulking was achievable at low F/M loadings in a completely-mixed reactor configuration.

Nine reactor configurations were examined during this study. Compartmentalizing the aeration basins into two, four, eight and 16 equal-sized reactors did not cure nor prevent filamentous bulking. When the initial compartment size was reduced to 1/74 of the total aeration basin volume, sludge bulking was controlled. Multiple small basins were unnecessary in this control scheme. Brief studies were also conducted with two small anoxic compartments (each 1/64 of the total basin volume) preceding a larger completely mixed basin. This configuration was unsuccessful in achieving stable bulking control.

The authors showed that sludge volume index (SVI) could be related consistently to the organic loading on the initial compartment as measured by F/M or soluble COD. No consistent relationship occurred between SVI and dispersion number or floc loading.

The mechanism by which the use of selectors or the employment of plug-flow aeration basins produces low sludge volume indices is still unresolved. The authors proposed three possible hypotheses for the success of these configurations. The first was that the presence of high levels of materials found in the small initial reactor may be inhibitory to filamentous organisms. A second proposal indicated that a selection might take place in this initial reactor whereby floc-forming organisms grow faster at higher organic loads than filamentous organisms. Finally, it was proposed that a selection of floc formers may occur because they can store and utilize storage products more readily than the filamentous organisms. The authors further presented data to illustrate the importance of substrate absorption in the initial compartment. They demonstrated that SVI decreased as the amount of substrate removed by absorption, rather than by oxidation, in the initial compartment increased.

Currently, this technique is being tested at a 7.5 ℓ/min Phostrip pilot plant at Central Contra Costa Sanitary District in California. Two 1/74 total aeration basin volume selectors are achieving bulking control at this facility at a range of F/M loadings of from 0.2 to 0.9 g COD removed/g MLSS·d.

The formal discussion by Boyle (U.S.A.) pointed out that this study substantiated earlier work reported for similar loading conditions but that quantitative differences in achieving positive results (based on initial compartment loading) was likely due to differences in wastewater characteristics. He also pointed out that a good deal of variation existed in the predominant filamentous organisms during this laboratory study. The successful reactor configurations employed by these authors appeared to prevent or cure bulking caused by all of these types. He suggested therefore that the control mechanisms might vary for a variety of reasons.

The authors agreed with the discussion by Boyle (U.S.A.) and emphasized the fact that waste characteristics play a fundamental role in the techniques used to control bulking. Based on their most recent experiences at Richmond, California, the degradable soluble fraction of the waste material must be absorbed in the initial compartment. Thus, the influent concentration of soluble substrate will have a very fundamental role in the design of the initial contacter unit.

In the floor discussion, Kroiss (Austria) cited two examples of the use of reactor configurations to control bulking. The first, a highly loaded plant for the city of Vienna, was piloted about eight years ago. Successful bulking control has been achieved in the full-scale plant for two years through the use of two anoxic reactors in series each with 1/8 of the entire system volume. These reactors are followed by three additional aerobic tanks in series, each with 1/4 of total volume. The other example presented was a study with an industrial waste plant. He cited substantial differences from pilot- to field-scale operation and indicated that successful bulking control was achieved through the use of an initial compartment with 1/40 of the total volume followed by a large completely stirred reactor. He emphasized the importance of the first compartment in removing up to 50 percent of the oxidizable substrate. The author acknowledged this work as further evidence of the importance of waste specificity on the design of the initial selector. He felt that there is a way to go before we will understand why different configurations give different results.

Roberts (South Africa) suggested that there may be a relationship between filamentous organisms and denitrifying activity in activated sludge. He asked whether denitrifiers are predominantly filamentous or whether filamentous organisms might develop a symbiotic relationship with nitrifiers in activated sludge. The author responded that he had no knowledge as to whether filamentous organisms denitrify but that he felt that filamentous organisms should not be too important to the denitrifying process since they make up only 1 to 2 percent of the total microbial population during bulking conditions.

Kerdachi (South Africa) asked how bulking sludge was quantified and how the sludge volume index (SVI) was measured. It was his experience that at high mixed liquor concentrations (4000 mg/ℓ or greater) SVI was meaningless. Finally, he raised questions regarding the presence of dissolved oxygen and bulking sludges. The author indicated that SVI was measured using an unstirred settling test at a constant initial solids concentration of 2.5 g/ℓ. This test appeared to give results similar to the German diluted-SVI method. Bulking sludge was quantified as a sludge with a SVI exceeding 150 mℓ/g. High dissolved oxygen concentrations were maintained (greater than 2.5 mg/ℓ) to prevent filamentous bulking, but the author agreed that pin-point floc can result at high dissolved oxygen concentrations in lightly loaded plants.

Wiechers (South Africa) asked if a critical study has been initiated to evaluate the mechanisms involved in bulking control by the use of selectors. He indicated that many bulking problems and their solutions are site specific and asked if any work had been done on scale-up of this laboratory work to full-scale operation. The author indicated that work was now underway at the University of California-Berkeley using several pure culture isolates of filamentous organisms. He felt that it would be some time before specific mechanisms for control would be delineated. Scale-up at Central Contra Costa was sheer luck, and at this time no scale-up work has been done.

B. Paper No. 5: "Obtaining Secondary Treatment with RBC Underflow Clarifiers," by I. L. Bogert (U.S.A.)

This paper presented the results of a one-year experimental study at Edgewater, New Jersey, to evaluate the effectiveness of the installation of rotating biological contactors (RBC) in modified primary sedimentation tanks to provide secondary treatment. A single primary tank was divided into two horizontal zones separated by an intermediate floor. Four RBC units were installed in the upper zone. High-rate sedimentation preceded the process to remove grit and floatables. Three loading conditions were evaluated--a low loading condition to insure an effluent quality better than 30 mg/ℓ for BOD and suspended solids; an increased load to achieve a 30 mg/ℓ effluent quality; and a high load condition to stress the system.

The study indicated that the RBC-underflow clarifier concept was an effective secondary treatment process capable of meeting current United States EPA effluent standards for BOD and suspended solids. Pretreatment for removal of grit, floatables and screenable materials was required. The author indicated that organic removal efficiency was limited by dissolved oxygen concentrations and that seasonal effects appeared to be minimal.

In formal discussion by Molof (U.S.A.), several questions were raised regarding the experimental results and interpretation. No rotational speeds (a parameter of substantial importance in oxygen transfer in RBC systems) were presented in the paper, and the type of media surface was not described. The insensitivity of the system to a temperature difference of about 15°C between summer and winter was also of some surprise considering the historical literature on other fixed film systems. The discusser suggested that the lack of response to this temperature difference could be due to dissolved oxygen limitations during the high temperature experiments. The discusser further questioned the value of the kinetic model presented because soluble BOD data were measured as a 24-hour composite whereas dissolved oxygen values were presented only during peak-flow periods. Finally, the discusser felt that response to increased BOD loadings may have been due primarily to decreased hydraulic residence time (caused by increased hydraulic loading) rather than organic overloads. The author responded by indicating that many of the details of this study appear elsewhere in an EPA report on this investigation. He agreed that dissolved oxygen might account for the apparent insensitivity of the process to seasonal temperature changes.

Seyfried (Federal Republic of Germany) asked if clogging was a problem at high organic loadings. The author indicated that there were no problems with clogging.

C. Paper No. 8: "Optimization of Nitrogen Removal in the Single Sludge Activated Sludge Process," by A. C. van Haandel, P. L. Dold and G.v.R. Marais (South Africa)

Dold (South Africa) outlined considerations which led to the development of a design procedure for optimal nitrogen removal in the single-sludge nitrification-denitrification system. The design procedure was presented as a series of rules to allow rational selection of process configuration and operational parameters. The basic concepts governing these rules have been reported previously by these investigators and were briefly reviewed.

Nitrate profiles in the predenitrification plug-flow reactor showed two linear phases described by rate constants K_1 and K_2. Only a single linear phase for nitrate reduction was observed in the post denitrification reactor (described by K_3). The two-phase nature of denitrification in the predenitrification reactor was found to arise from the two-substrate nature of the influent COD in domestic wastewater. In the design procedure, two conflicting requirements must be met--efficient nitrification must be insured and maximal denitrification must be achieved. The requirement for nitrification sets a limit on the anoxic fraction allowed in the process. The mass of nitrate produced per unit of COD depends on the influent TKN/COD ratio whereas the amount of denitrification achieved depends chiefly on the mass of readily biodegradable influent COD and the anoxic mass fraction. For any set of wastewater characteristics including influent TKN/COD ratio, rapidly biodegradable COD fraction, and maximum specific growth rate of nitrifiers, a set of curves may be developed for any temperature. These curves may then be used to rationally select process configurations to optimize nitrogen removal.

In formal discussion, Matsuo (Japan) reported on the design model and procedure used by his group in Japan for a Bardenpho-like process called the Inner Recycle Process or Denipac. Developed in 1971, the process flow sheet is identical to the Bardenpho system except that methanol or isopropanol is dosed to the post anoxic reactor. Basic differences in the design model used by Matsuo (Japan) from those presented by the authors included: (1) The assumption that the decay rate for nitrifiers in the anoxic and aerobic zones is negligible; (2) The assumption that the endogenous respiration rate of heterotrophes in the anoxic zone is also negligible, and (3) No constraint for the volume fraction of the anoxic zone. The design procedure, which was briefly outlined, was similar to that presented by the authors but included an evaluation of the limitation of oxygen supply in the aerobic reactor. The use of an aerobic sludge age was also introduced into the design procedures to replace system sludge age. The discusser also briefly alluded to problems with setting and optimizing reactor MLSS levels in this system.

Dold (South Africa) expressed great interest in the parallel, yet independent, development of similar treatment configurations, models and design procedures for nitrogen removal. He pointed out that the addition of easily biodegradable substrate to the post-denitrification reactor would greatly improve the capacity of that reactor and that its behavior would be the same as that of the pre-denitrification reactor. The assumption of negligible endogenous respiration by nitrifiers would not result in any significant differences in design between the two groups since Matsuo (Japan) employed an aerobic sludge age whereby the Cape Town group employed a total system sludge age and nitrifier decay. The author cited experimental evidence, however, that supported the need for the inclusion of a heterotrophic endogenous respiration constant in the design approach. Finally, the author felt that the provision for aeration limitations in the aerobic reactor by Matsuo (Japan) represented a useful extension of the theory.

In the floor discussion, Roberts (South Africa) remarked on the substantial differences in the specific growth rate constant for nitrifiers used by Matsuo (Japan) (0.214 d^{-1}) versus that often seen for domestic wastewater (0.65 d^{-1}) and asked if the differences might be due to measurement errors. Marais (South Africa) responded that the measurement was very complicated, being obtained by simulation using experimental data collected in the laboratory by switching the system from aerobic to anoxic. He indicated that in Cape Town, two domestic wastewaters give significantly different values of the growth rate and that he has seen values ranging from 0.1 to 0.7 d^{-1}. Without knowing what affects this rate, engineers tend to be conservative selecting a design value.

Wiechers (South Africa) asked what effect the optimization of nitrogen removal in the single sludge system had on sludge settleability. Marais (South Africa) replied that initially it was related to anoxic sludge mass. Now they have found that it is really a function of hydraulic residence time in the anoxic zone. If this time is greater than one to 1.5 hours, sludge setteability deteriorates. The same phenomenon also applied to the Phoredox processes with respect to the anoxic zones, but for some reason setteability is unaffected by the residence time in the anaerobic zone.

Beekman (South Africa) asked whether any studies had been done with settled wastewater, in addition to those presented for unsettled wastewater. Ekama (South Africa) replied that process calculation can be used for both settled and unsettled wastewater and that laboratory and pilot-scale plants have been operated with both types of wastewater. Since primary clarification removes more COD than TKN, the TKN/COD ratios for unsettled wastewater are higher, and it is, therefore, more difficult to remove all of the nitrogen without addition of methanol in these systems.

Meiring (South Africa) asked the authors to describe the basic differences between Phoredox and Bardenpho processes. Diagrams were presented to illustrate the two flowsheets. The Phoredox process is designed for simultaneous biological nitrogen and phosphorus removal. The Bardenpho process is designed for biological nitrogen removal only.

Jenkins (U.S.A.) asked whether the organisms causing bulking were identified. Marais (South Africa) indicated that bacteriologists had identified the organism most often seen as as a blue-green algae. He described the organism as a thin filament which developed nodules just prior to death. Jenkins (U.S.A.) indicated that in studies with the Phostrip process in California, no bulking was observed with solid retention times in the anaerobic reactor up to 10 hours, which corroborated earlier comments by Marais (South Africa). Jenkins (U.S.A.) asked whether the model was supported by any data. Marais (South Africa) indicated that the paper presenting experimental data was published in *Water Research* in 1981. Data collected over seven to eight years were used to develop the model presented in this paper.

Pretorious (South Africa) was interested in how often the laboratory vessels were cleaned of wall growth that might catalyze biochemical reactions. Marais (South Africa) indicated that reactors were kept meticulously clean. Once per week sludge was removed and the reactors were thoroughly cleaned. He indicated that much of the bad data published was due to wall effects in the system.

Barnard (South Africa) emphasized the importance of scale-up from laboratory to full-scale plants. He indicated that the aeration system can have an important influence on process operation. He cited a case in Copenhagen where several surface aerators were turned off. This created anoxic zones which resulted in filamentous bulking. He felt that diffused air systems were more readily controllable and that gas flows could be turned down to avoid oxygen entrainment in the post denitrification tank without creating anoxic zones in the aeration tank. Marais indicated that direct scale-up was possible if one can avoid the effect of wall growth.

D. Paper No. 11: "Fate of Heavy Metals and Potential for Clinker Formation During Pilot Scale Incineration of Municipal Sludge," by H. W. Campbell, P. J. Crescuolo and T. R. Bridle (Canada)

Bridle (Canada) presented data on a pilot study used to develop a data base on the fate of heavy metals contained in municipal sludge and the potential for clinker formation when incinerating this sludge. A factorial design was developed examining the influence of the independent variables--incinerator temperature, throughput rates of sludge and center shaft speed--on the fate of selected metals, organic carbon and clinker formation. An Envirotech BSP pilot multiple-hearth incinerator with six 0.76-m hearths was used for the study.

The author reported that phosphorus, chromium, nickel, copper, lead and zinc were conservative and remained in the ash. Cadmium volatilization was a function of temperature ranging from 25% at 760°C to 56% at 928°C, but most of it was recovered in the scrubber water. About 26% of the arsenic was classified to the scrubber water but not to the atmosphere. By inference, greater than 99% of the mercury was classified to the gas stream but lack of samples from the scrubber precluded conclusions regarding the amount reaching the atmosphere.

Clinker formation was found to occur only at the highest temperature (928°C) with long residence times (e.g., lowest rates of input and center shaft speed). This clinker formation could be eliminated at high temperatures by operating at high sludge throughputs. Carbon destruction was essentially complete under all experimental conditions.

The formal discusser, Gerber (South Africa), indicated that, among other reasons, cost considerations discouraged incineration of municipal sludges in South Africa. He asked about Canadian costs. Bridle (Canada) responded that sludge incineration was practiced in Canada where there were heavy urban densities. Recent cost estimates made for Burlington, Ontario, indicated a value of $200/ton (Canadian).

Gerber (South Africa) asked if the author could account for differences found between this work and work done in the United States with respect to cadmium volatilization. United States study showed that cadmium was classified with the ash. The authors replied that they had no idea why they were not able to account for the cadmium. They speculated that differences between this work and that done in the United States might be due to different incineration systems since the study in the United States was performed with a fluidized-bed incinerator and with completely different ash removal techniques.

Gerber (South Africa) asked about the quality of the scrubber water and its influence on treatment plant operation. The authors indicated that scrubber water was used in a once-through mode for both pilot studies and at Hamilton. Cadmium concentrations of 20 μg/ℓ were measured in this scrubber water and arsenic was found to be 22 μg/ℓ.

Finally, Gerber (South Africa) asked about scale-up of pilot plant studies to full-scale operation with respect to clinker formation. The authors indicated that they did not know how to do this but felt that manufacturers did have some idea about how to go from pilot- to full-scale operation. They indicated that the objectives of their study were to obtain general indications of performance, not to provide quantitative numbers for scale-up.

In the floor discussion, Ruffer (Federal Republic of Germany) pointed out that heavy metals could be fixed in the ash so that resolution is not possible once the ash is disposed. This method, published over 20 years ago, fixes the metals by a melting process forming a clinker. The author concurred with this.

Kugel (Federal Republic of Germany) indicated that problems at a wastewater treatment plant in West Germany were encountered when incineration of a sludge high in reduced chromium (Cr^{+3}) was oxidized to Cr^{+6} during incineration. The author indicated that no measurements were made of valence state in this study but that another study done in Burlington, Ontario, showed that chromium in the incinerator ash was immobile.

Richardson (South Africa) asked what the nature of the sludge was and how it was dewatered. He also asked if there were emission standards in Canada for incinerator discharges. The author indicated that the test sludge was a mixture of municipal primary plus waste-activated sludges. He indicated that the primary sludge was dewatered on coil filters and the waste-activated sludge was thickened by dissolved air flotation. There are no emission standards for metals in Ontario province for municipal incinerators, only a particulate standard.

E. Paper No. 14: "The Use of Rheology for Sludge Characterization," by H. W. Campbell and P. J. Crescuolo (Canada)

Experimental work was conducted at the Wastewater Technology Center in Burlington, Canada, to evaluate the use of rheology as a process control parameter for sludge conditioning. This work was initiated after the authors found that an apparent relationship existed between a peak in the shear stress-shear rate curve for a conditioned sludge and the polymer dose required to give efficient dewatering in pilot-scale trials. Their goal was to develop a standardized procedure for testing sludges in a commercial viscometer and to determine the effect of machine variables on the resulting sludge rheograms. Finally, he presented preliminary results on the interpretation of these rheograms. This was a report on preliminary results of this method. The author was enthusiastic about the potential of this method but was clearly cautious about its use without further study and evaluation.

In formal discussion, Marchandise (France) raised a number of questions regarding the usefulness of the method, the wide range of variability in the data and the uncertainties associated with the theory. His first remarks raised the question as to whether rheology offers a benefit for process control that is better than parameters currently used, such as specific resistance and capillary suction time (CST). The author indicated that he was not sure that rheology was a better method. However, he indicated that it has been used by industry as an on-line control parameter. If one can understand what is happening, he felt the use of the viscometer as an on-line control device would be superior to other methods now being used.

Marchandise (France) inquired about discrepancies that existed between rheograms in several of the figures presented. The author indicated that the rheograms were obtained from different sludges. He also indicated that the differences seen in some of the curves were due to the shearing of the flocculated sludge prior to being introduced into the viscometer. He also indicated that he did not feel it would be possible with this method to scale-up to full-scale conditioning.

The discusser was also disturbed by the fact that some sludges did not demonstrate characteristic peaks and asked if this was widespread. The author again indicated that the curves represented a wide range of solids concentration and physical characteristics which will contribute to the character of the rheogram.

Marchandise (France) questioned the technique used to relate rheology to sludge particle size since the sludges were diluted and an electrolyte was introduced. The author agreed with this and indicated that he felt that the relative mean-particle sizes were probably reasonable but he did not know about the absolute sizes.

In floor discussion, Möller (Federal Republic of Germany) asked if parallel tests have been performed between viscometer and CST and, if so, did they produce parallel results. The author indicated that parallel tests were performed and when a peak was detected on the rheogram, the CST values were in the range of 10 to 20 s. This correlated well with studies done at their laboratories with conditioned sludges (i.e., super-flocculated sludges normally yielded CST values of 10 to 15 s). Möller also expressed concern over the effect of conditioning on particle size and the influence of shear in the viscometer on the data obtained. The author indicated that as the polymer dose increased, more breakdown would result but the resulting particle sizes were still greater than those with the next highest polymer dosage. He agreed that more work still needs to be done on this.

Rose-Innes (South Africa) indicated that he has been doing work with waste-activated sludges (concentrations up to 6%) using a viscometer to evaluate sludge flow in pipelines. He also found the characteristic peaks described by the author at high sludge concentrations. He indicated that depending on the rotor head used, one could find the sludge moving from laminar to turbulent flow which would be of concern. He also indicated that for non-Newtonian fluids such as the sludges studied by the author, shear rate was not proportional to turn rate and that variable calibration would have to be incorporated.

Seyfried (Federal Republic of Germany) asked what practical purpose was served by this study. The author emphasized the importance of developing a control method with rapid utility. He felt this method would provide operators with quick information on changes in sludge characteristics.

Dick (U.S.A.) indicated that he felt the peak in flow curves were unique in rheology studies and asked whether the author knew why it occurred. The author indicated that he was unsure but it may relate to particle size or particle size distribution (or both). It might also be due to the realignment of mass conglomerates in the viscometer.

IV. CRITIQUE OF SESSION

The papers dealing with filamentous bulking and nitrogen removal were well received and enthusiastically discussed. There has always been a great deal of interest in activated sludge bulking control and Paper No. 2 stimulated a great deal of interest in the mechanisms of control affected by compartmentalization. It appears that there is general concurrence among researchers that basin configuration plays a very significant role in effective and reliable control of filamentous bulking. The major questions now deal with how to rationally design these initial contact basins, whether there are decided advantages to anaerobic versus aerobic contactors and, of course, the mechanisms for control.

The paper on nitrogen removal (Paper No. 8) was one of a series of excellent papers produced by the University of Cape Town. These investigators are clearly among the leaders in this field and the discussion was lively and informative. It was very interesting to note the interest expressed by the Cape Town group regarding the parallel work being done in Japan which was previously unknown to them. A number of useful questions were also raised regarding design constraints, bulking problems and scale-up.

The discussion on the use of RBCs in primary clarifiers received little attention by the delegates, perhaps because it was a summary of a more detailed report that was unavailable to most. Most concern centered around the data base and its interpretation. The paper on incineration of sludge received some discussion, primarily by those delegates outside of South Africa where incineration of sludge is not normally practiced. The question of heavy metal recycle in the environment prompted several interesting discussions. Finally, the proposed method of the use of viscometers for controlling sludge conditioning received a mixed response. Considerable doubt was raised by several discussers as to the value of such an in-line control device, at least until more is known about rheograms.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The subject of activated sludge bulking continues to be one of the high priorities in operation research in the United States. Considerable progress has been made over the past eight to 10 years in verifying that reactor configuration is an important factor in controlling filamentous bulking. Since a greater emphasis is being placed on nitrification in this country, the lower loaded plants (and, therefore, potentially a greater likelihood of filamentous bulking) will be a focal point for these control strategies in the near future.

The removal of nitrogen in wastewater will continue to receive substantial attention in the United States. The contributions of South Africa to a better understanding of biological nitrogen (and phosphorus) removal, and the design and control of such processes are of great value to the United States research program. The paper presented on this topic (as well as several others) provides additional useful information to our current data base for design and operation of these processes.

The retrofitting of existing overloaded plants in the United States is becoming a national effort. The contribution of the RBC to the upgrading of plants may be significant. The paper presented in this section may stimulate further research in the application of RBCs to certain retrofit situations.

I. SESSION

A. Day: Tuesday, March 30, 1982
Hall: B
Time: 8:30 a.m. to 12:05 p.m.

B. Theme of Session: Desalination and Filtration

II. REVIEWER

A. Name: Edward S. K. Chian

B. Position and Affiliation: Professor of Environmental Engineering
Georgia Institute of Technology
Atlanta, GA

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 17: "Slow Sand Filtration for Cercarial Control in North Cameroon Village Water Supply," by K. Kawata (U.S.A.)

The control of cercariae of human schistosomes in the water supply of North Cameroon was studied with the use of locally available and acceptable slow sand filters. Based on a literature survey, no consideration was given to sand characteristics or realistic operating parameters for the removal of "old" cercariae with slow sand filters. The study was conducted with *Schistosoma mansoni* cercariae within one to two hours after shedding. The parameters under study involved filter sands having three effective sizes of various uniformity coefficients, three filtration rates and two depths of sand bed. In the light of these test results, design parameters were selected with effective size of the filter sand to be 0.3 mm or less with a uniformity coefficient of 2.0 or less. The initial bed depth was selected to be 1.2 m. The bed may be scraped down in the cleaning process with the caveat that the sand depth must not drop below 0.6 m. The designed filtration rate was 0.12 m/h or less. Good practice required that filters be thoroughly conditioned before being placed on line and at no time should the sand be allowed to dry out. When beds are allowed to dry, they can shrink and pull away from walls which can create pathways for cercariae to pass through.

Williams (South Africa) indicated that the subject is of particular interest in South Africa. The National Institute for Water Research in Pretoria is presently commencing a project to investigate appropriate design criteria for slow sand filters to be used under South African conditions. The author has shown that cercariae can be effectively removed by slow sand filters based on the design criteria included in a WHO booklet published in

1974. This provides added advantage in addition to turbidity and organic pollutant removal. However, there are two practical points associated with operation of slow sand filter for cercariae removal. First, in order to provide effective cercariae control for a community, an appropriate supply of filtered water is needed so that the local people will use this supply of water in preference to the traditional contaminated water supply. Second, when the slow sand filter is to be cleaned, the *Schmutzdecke* accumulated at the surface should be scraped off and the spent sand should be allowed to stand for two days prior to disposal to safeguard workers from the cercariae-contaminated sands. Two questions were raised. First, what would be the role of the *Schmutzdecke* in the removal of cercariae? Second, the experimental results were based on six to ten runs. The slow sand filters are normally operated for only one to two months between cleaning. Is there cercariae breakthrough during a longer filter run?

The author replied that the *per capita* income in the area is $30 (U.S.A.) and a distribution system or even a pumping station is not economically practical. The goal for the local government is not to improve the health of the people but to see that, whatever is done, the health condition would not be any worse than it is now. Therefore, they are quite realistic about what can be done with their water supply system. As to the question of the role the *Schmutzdecke* played in the removal of cercariae, I would say that the removal efficiency will increase as the *Schmutzdecke* is being built up. A bacterial buildup would also tend to enhance cercariae removal, as shown in a review paper prepared by the author for WHO. As the *Schmutzdecke* is slowly building up, an improved removal of cercariae is expected.

Pepkie (Canada) inquired about the wall effect of using a 15-cm diameter column slow sand filter. Based on literature, the wall effect can be eliminated by using 2.5-cm diameter sand column coated with sand adhered on the wall. The author was not concerned with the wall effect with the use of a 15-cm diameter sand column.

VanVuuren (South Africa) was concerned with the use of slow sand filters for treating bacterially contaminated water for boiler water. He asked if the slow sand filter could be used to partially disinfect contaminated ground water. The author pointed out that in Stockholm the slow sand filter is used following the rapid sand filter for polishing purposes and produces an excellent quality water. Therefore, the slow sand filter can be used for a number of applications including partial disinfection.

B. Paper No. 19: "Characterization of Fouling Potential for Pressure-Driven Membrane Processes: A New Simulated Flow Cell," by R. H. Reed and G. Belfort (U.S.A.)

The paper described the development and testing of a new apparatus, simulated flow cell (SFC), for the characterization of fouling potential of pressure-driven membrane processes. This apparatus takes into consideration the tangential flow across a membrane surface in order to accurately predict how feed water foulants behave in a flow field existing in the operation of an actual reverse osmosis system. The SFC was tested using irradiated polycarbonate membranes supplied by Nuclepore along with the use of polystyrene latex spheres (PSL) as synthetic particulate foulants and also using actual water and wastewater as natural foulants. The parameters under study included membranes of various pore diameters tested over a wide range of flow conditions, expressed in terms of Reynolds numbers. In addition, the newly developed dynamic SFC was evaluated along with the conventional static non-flow cell (NFC) so that comparisons of plugging factor after various periods of operation can be made with both systems. When using the 0.1 μm Nuclepore membrane, all tests in the SFC for axial velocity larger than 1800 cm/s showed significantly lower plugging factors. For axial velocities smaller than 1117 cm/s, SFC tests showed no difference in plugging factors as compared to the NFC tests. The author concluded that the results suggested that the newly developed SFC can be used to more accurately predict fouling characteristics of an actual reverse osmosis (RO) membrane system.

The formal discusser, Chian (U.S.A.), commented that the definitions of "non-flow" and "simulated-flow" were confusing. There is actually transmembrane flow occurring in the so-called non-flow cell and it was suggested that the term "non-simulated flow" be used in lieu of "non-flow." Also, the term "axial flow" as used by the authors to indicate flow sweeping over the circular membrane surface is inappropriate. A more appropriate term would be either "bulk-flow" or "radial-flow." In addition to editorial comments, the discusser believed that membrane fouling involved plugging by either physical deposition of colloidal particles or chemical interaction of the colloidal materials with the membrane surface or both. The former can be reduced by hydrodynamic shearing. The advantage of the newly developed SFC lies in its ability to reduce greatly the physical deposition that occurs in a real membrane system. The conventional NFC test overestimated the fouling characteristics of a membrane since it was unable to differentiate the pure physical deposition from the so-called chemical interaction of the colloidal materials with the membrane surface.

The author replied that most of the comments were additive and accepted them in the good intentions that were given. However, the author did not believe that attachment mechanisms and transport mechanisms were important. In fact, he has a whole research group working on the dynamics of the particles on the membrane surfaces which is, in fact, the first step of what is called the two-step process; namely, the particles have to first move to the site of attachment and then become attached there. It is very analogous to the flocculation, coagulation and filtration, i.e., the particles have to get to the membrane site. One can go through a highly intensive mathematical analysis to predict the dynamics of the transport process. The trajectory can be predicted and calculated very accurately. As far as the comments on the attachment mechanisms and the interaction forces, they can vary similar to the effect of pH, shearing lift and ionic strength on the stabilization and destabilization on the colloids. In fact, a higher flux was observed in the presence of salt in the solution which results in building up a concentration polarization layer on the membrane surface. This is contrary to what would often be predicted for a lower flux. Evidently, destabilization of colloidal matter in the presence of a higher ionic strength appears to play the role of resulting in a lower hydraulic resistance packing layer on the membrane surface.

As to data in Table 4, absolute Reynolds numbers change with the distance away from the center of a membrane. A particular point was selected for the computation of the Reynolds number. The relative Reynolds numbers, which define the various flow regimes such as laminar, transition and turbulent, were the concepts of interest.

Botha (South Africa) asked if any correlation had been made between values obtained from SFC testing runs to that of fouling with an actual RO system. He indicated that there was no correlation between membrane fouling with the data obtained from the conventional NFC testing runs. The author considered this to be a most important question. His answer was that he did not have the resources for making such correlations. However, he was in the process of finalizing negotiation with a large French membrane company to set up a cooperative program to run such correlation experiments. Also, Mutachen (U.S.A.) of the University of Southern California has a copy of his cell design to check out with the treatment of agriculture runoff with the RO system.

DuVediell (South Africa) commented that the Nuclepore filters used in the SFC were expensive. Are they actually indispensable as it was stated in the paper? Also, he questioned the pressure applied in the SFC (30 psi) whereas an actual reverse osmosis operation is operated at a pressure of 400 psi and higher. What are the pressure effects on the cake deposited on the membrane?

The author replied that due to the competition from Germany the prices of the Nuclepore membrane are expected to fall. Also, the membrane can be re-used if proper care is taken not to tear it during the cleaning process. However, if one compares the costs of operating a RO system with that of the Nuclepore membrane employed in the SFC tests, the latter are insignificant. The author agreed that he had not simulated the pressure applied in the actual RO system since the SFC was designed as a quick, simple and inexpensive testing system. This indeed is the limitation of the system.

Hendry (SA) commented that conventional plugging tests were intended to be used as a crude measurement of presence of colloids, and should not be used to correlate fouling potential of a water on an actual RO membrane. He was trying to develop measurements of size distributions of colloidal particles in order to correlate RO membrane fouling potential.

C. Paper No. 21: "Desalination by Continuous Ion Exchange Based on Thermally Regenerable Magnetic Microresins," by B. A. Bolto and E. A. Swinton (Australia)

The paper described the unique hydrodynamic and kinetic properties of "Sirotherm," thermally regenerable desalting resins made in the form of magnetic microbeads, and the development and testing of continuous contacting systems which exploited these properties. This process was designed to partially desalt water and wastewater containing 500 to 2000 mg/ℓ of total dissolved solids on a large scale. It consumes no chemicals; only a small amount of low-grade heat is needed for regeneration. Typical salt removal of 80% was obtained. The advantage of using the magnetic ion exchange resins was their ability of attaining a high reaction rate and clumping together for better separation. A novel multistage countercurrent contactor utilizing the principles of distillation and solvent extraction was evaluated on laboratory and pilot-plant scales. This process is truly continuous as compared to the conventional ion-exchange resin system and is simple and economic to operate without requirement of preclarification of raw water. However, the process suffered from a few limitations; namely, no simultaneous removal of divalent and monovalent ions, and sensitivity to oxidation and organic compounds. These drawbacks can be corrected by pretreatment of raw water with strong ion-exchange resins for softening, addition of sodium sulfite for deoxygenation and the use of organic traps.

Carr (South Africa) initiated the discussion by presenting an elaborate analysis of the relative advantages and disadvantages of desalination using the Sirotherm process, SP; continuous countercurrent ion exchange, CCIX (presented by Hendry in Paper No. 23); and reverse osmosis, RO. The parameters concerned involved pretreatment requirements, product water recovery, costs of water produced, energy requirements, service life, simplicity of operation and commercial availability. He summarized that CCIX has excellent service life and requires literally no pretreatment, whereas RO is more energy efficient and simpler to operate. Both processes are commercially available. In conclusion he stated that, for the removal of salinity from water, RO is the preferred process, whereas for removal of salinity from wastewater, CCIX and perhaps SP are preferable. The discusser invited comments from the author on the SP and from the audience on the RO process. Also, he asked the author to elaborate on the difficulties encountered during the development of the non-continuous and the continuous operations of the Sirotherm process.

The author replied that up to 85% water recovery was attainable. The life of the resin was estimated at five years for a small plant and longer for a larger plant. The plant was indeed simple to operate. The commercial availability of the SP plant and the resins depends upon the success of the demonstration plant. The problems on pretreatment have been resolved satisfactorily by using a conventional cation-softening process and by using inexpensive sodium sulfite to control oxygen. As to the difficulties encountered with the non-continuous plant, the cyclic process posed problems in keeping oxygen out and pH control was difficult. Economically, SP is not in competition with RO for small plants, but for a larger plant, a single plant treating 20 to 50 million liters a day is possible and would be more economical. An RO plant would require thousands of modules for a plant of equivalent size.

Botha (South Africa) questioned the vulnerability of the resin to oxygen during periods of shutdown, interference by monovalent chloride and divalent sulfate in water, and the lack of price information.

The author replied that the oxidation of resins was a slow process, the loss of only 1% of the resin occurred in a few hours. There were no problems with mono- and divalent anions, only the cations were of concern due to the chelation on the carboxylic group on the resin. The cost information SP will be evaluated in parallel with an electrodialysis (ED) process. Currently, the company is not ready to market the process. A more comprehensive cost figure will be available later based on large-scale plant studies.

Hendry (South Africa) asked if water recovery was related to the heat balance in the cooling system. He also suggested it was better to use NaCl softening. The author replied that water recovery was limited by the reflux system in the still. The yield is based on the difference between the two equilibrium curves on the Thiele diagram. Operation at 95°C appeared to be an upper limit. The softening process should be designed on an individual basis.

Handle (South Africa) asked for elaboration on the simultaneous removal of mono- and divalent ions. The author said that the simultaneous removal of mono- and divalent ions with SP was not economical. The conventional cationic exchange resin was about the cheapest means of removing calcium and magnesium.

D. Paper No. 23: "Continuous Countercurrent Ion Exchange for Desalination and Tertiary Treatment of Effluents and Other Brackish Waters," by B. A. Hendry (South Africa)

The paper described the development of a continuous countercurrent ion exchange (CCIX) process for desalination of mineralized effluents and brackish water. The process utilized macroporous resins in a strong cation/weak anion sequence. The use of a weak anion resin had an added advantage of removing organic matter from the wastewater effluents which resulted in 70% reduction of the humus-like COD materials along with color and odor removal. During a period of two years of continuous operation without pretreatment, no significant fouling or loss of resin capacity was observed. Sulfuric acid was used for the regeneration of the strong cation resin whereas lime was used for regeneration of the weak anion resin. Water recovery was improved from 80% to 90% by using a new technique involving a five-column system with reuse of spent regenerants. Based on a careful cost estimate, the unit costs of water were 30 to 40 cents (U.S.A.)/m^3 for removal of 500 mg/ℓ of TDS.

The prepared discusser, Priestley (Australia), pointed out that although reverse osmosis is the most fashionable means of desalting brackish water, the in-depth exploration by the author of the use of the old-fashioned, ion-exchange resins was encouraging. CCIX as developed by the author removed not only salts but also ammonia, nitrate and organic matter. The use of an innovative recycle of excess acid allowed stoichiometric use of sulfuric acid for regenerating the strong cation resin, whereas the use of a low-cost lime for regenerating the weak anion resin provided added economic advantage to the CCIX process. In order to prevent precipitation of calcium from occurring, a fluidized bed would be desirable. However, most of the anion resins have a density close to that of unity. The use of a heavier anion resin by the author enhanced the fluidized bed process. The discusser encouraged the author to collaborate with researchers working on the heavier magnetic resins. Whereas it was relatively easy for an engineer to design a two-component system, it was virtually impossible to deal with a multicomponent system which was even more complicated with calcium sulfate precipitation. The author's effort in conducting a matrix study to explore the real situation was certainly encouraging. The discusser asked whether the economics could be improved further with the use of two equivalents of acids per cation. He also inquired whether the kinetics of the reactions with the resins were studied and about the availability of the resins. He requested the author's views on the advantages and disadvantages of using supersaturated calcium sulfate. Was it better to encourage precipitation within the resin columns or to learn how to handle the slurry instead of preventing scale from occurring?

In reply, the author evaluated the use of heavier anion results in a bench-scale study for the design of a larger fluidization column. He would like to look into the use of the higher density syndrix resin or the magnetic resins as described by Swinton in a previous presentation. In the distillation field, there were techniques available for the design of multicomponent systems. It really depended upon how clever one could be in applying them to the CCIX process and, so far, he could not find a way of doing it. A limited amount of theoretical work was in progress on the development of an unsteady-state mode for ion exchange. Hopefully, the techniques yielded could be applied to calculate the multicomponent system. The economics of acid equivalent was difficult to evaluate with available data. The half reaction times on strong cation resin were very short, i.e., 1-2 minutes, while the half reaction time for anion resin was long, approximately 20 minutes. On the supersaturation of calcium sulfate, it would be far better to get the liquid destabilized in the column rather than to carry it through the column as a supersaturated solution and trying to get it out afterward. By seeding gypsum in the bottom of the column, a 20% improvement in calcium removal was obtained.

Botha (South Africa) asked, "If the TDS were up by 500 mg/ℓ, would the costs increase by 13 to 14¢/m^3 based on the 35¢/m^3 figure given in the text? Secondly, if the COD were 30 mg/ℓ instead of 70mg/ℓ, would the same percentage of COD removal result?" The author replied that as TDS load increased, the chemical requirement also increased proportionally. Since there would be no changes in capital costs by increasing TDS from 500 to 1000 mg/ℓ, the costs would increase by 17¢/m^3 with the four-column system and 6¢/m^3 with the five-column system. Depending on the nature of the COD materials in the effluent, the same percentage of COD removal would maintain only when the COD materials were identical.

Eberly (Federal Republic of Germany) pointed out that sludge disposal costs were not included in the estimate. He also commented that for one-time reuse of treated wastewater, the ion exchange process might be satisfactory. However, for more than one reuse, it is necessary to desalinate with reverse osmosis.

The author replied that the costs for sludge disposal were difficult to estimate. The techniques employed in sludge disposal dictated the cost figures. He agreed that the use of resin was better for once-through desalination without blending. In the case of RO, water recovery could be improved greatly by blending with part of the untreated effluent to attain a desired level of TDS.

IV. CRITIQUE OF SESSION

Three papers (Papers No. 19, 21 and 23) formed an excellent theme--desalination with the use of innovative designs for the membrane and ion-exchange processes. However, Paper No. 17 dealt with neither desalination nor advanced control technology. The process involved was one of the most primitive ones used in the field of environmental engineering. Except for the use of viable cercariae in the research, the effects of other parameters studied on the performance of a slow sand filter could be expected, either intuitively or with common sense, e.g., the efficiencies of cercariae removal improved with the increase in the filter bed depth and with the decrease in sand sizes and filtration rates. The only contribution of the paper was the generation of a few numbers which could be used for the design of a slow sand filter to remove cercariae, even though the effects of forming a layer of *Schumtzdecke* on the removal of cercariae were not addressed. This created just too much of a contrast when compared with more advanced papers in membrane and ion-exchange processes, all of which involved a respectful level of engineering ingenuity in the development and testing of their systems.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The control of cercariae using a slow sand filter has limited application in improving public health in the United States. The interesting results on desalination with the innovated Sirotherm and the continuous countercurrent ion exchange processes may supplement the shortcomings of fouling of reverse osmosis membranes in desalinating wastewater effluents. The development of a simulated flow cell for the evaluation of fouling characteristics of a reverse osmosis membrane represents a step forward in evaluating the membrane process for use in renovation of water or wastewater. With this testing device, a more useful correlation can be established between the results obtained from laboratory testing and from actual operation of a prototype reverse osmosis system. This opens the way for more research to be conducted in the field of membrane areas. Since the United States is leading in the area of membrane research and development, the availability of the newly developed simulated flow cell, as presented by Belfort, would certainly aid in conducting fruitful research on membrane process applications.

I. SESSION

A. Day: Tuesday, March 30, 1982
Hall: B
Time: 1:00 to 4:35 p.m.

B. Theme of Session: Mass Transfer; Scale Up and Mathematical Modeling

II. REVIEWER

A. Name: Dipak Roy

B. Position and Affiliation: Assistant Professor
Department of Civil Engineering
Louisiana State University
Baton Rouge, LA 70803

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 25: "On the Mass-Transfer Characteristics Within Microbial Systems," by M. Onuma and T. Omura (Japan)

The diffusion coefficient within a microbial system was determined by both diffusion and kinetic studies on the basis of Fick's model and an effectiveness-factor model in order to predict the mass-transfer characteristics of this system. It was found to be dependent on the molecular weight and C/N ratio of the compounds and substrates used in the diffusion study. The transitional film thickness from a reaction-limited case to a diffusion-limited one was found to be about 150 μm in a kinetic study. The observed diffusion coefficient in the diffusion study was of the same order as that of the kinetic study.

The diffusion studies for DO, glucose, NH_4-N and PO_4-P were performed using a two-compartment diffusion reactor and a circulating reactor was used for kinetic studies. Diffusion coefficients for glucose and DO were observed to be independent of the film thickness in the range of 70-100 μm. The observed values of diffusion coefficients for DO and glucose in a biofilm were found to be 10 percent greater than the calculated value in pure water. Diffusion coefficients for glucose were observed to be dependent on the C/N ratio of the solute. It was reported to be constant in the range of C/N ratio of 0-10, whereas a decreasing trend of diffusion coefficient was observed with increasing C/N ratio above 10.

A linear relationship between the reaction rate and the film thickness was observed up to a critical value of film thickness of approximately 150 µm. Above the critical value of film thickness, the reaction rate remained constant. The overall reaction was considered to be limited by the biochemical reaction in cases of the film thickness less than the critical value, whereas the diffusional process was the rate-limiting step above the critical film thickness. The effectiveness factor, defined as the ratio of overall reaction rate and the ideal reaction rate, was observed to be dependent on the film thickness for diffusion limited case. The effectiveness factor was one for reaction limited cases.

Harremoes (Denmark) indicated that the experimental aspects of the research were inspired by the work of Williamson and McCarty and expressed the following reservations and questions: (1) In the experiment, biofilm was made up by dispersion of activated sludge flocs onto a porous filter. Flocs dispersed onto a filter may not behave in a similar manner as a biofilm; (2) The diffusion reactor was made up of two compartments and a slight difference in pressure between two compartments may significantly affect the results. How was the pressure in these two compartments maintained at same level?; and (3) How was the biofilm made non-reactive?

Harremoes (Denmark) commented on the diffusion coefficient reportedly being 10 percent greater in biofilm than in pure water. This is in contrast to values reported in literature which show diffusion coefficients in biofilms are approximately 50-100 percent greater than those in pure water. Diffusion coefficients have been reported to be dependent on the C/N ratio of the sewage in which activated sludge flocs are grown. Diffusion coefficients were observed to be 6×10^{-6} and 0.8×10^{-6} cm^2/s at C/N ratio 5:1 and 50:1, respectively. The drop in diffusion coefficient at a C/N ratio of 50:1 indicated that the bacteria were starved of N. When bacteria are starved of N, changes in bacterial species and extracellular polymer accumulation are believed to occur and may therefore affect the diffusion coefficient. It was felt that more information should be provided on recirculation filters with regard to the type of media used, possible concentration gradient in the filter, the dissolved oxygen concentrations, and the measurement technique of biofilm thickness.

As the film thickness increased, the reaction rate was observed to increase to a limit and then remained constant. This was interpreted in the paper as a transition from fully-penetrated film to partly-penetrated film. In a redox-reaction experiment, two substrates, glucose and oxygen, are involved. How can it be assured that the transition is due to fully- to partly-penetrated oxygen and not glucose? It appeared that at a 50 mg/ℓ glucose concentration, oxygen may be limiting. The critical film thickness of 150 μm is not an universal value and depended on the substrate concentration. Finally, the discusser felt that the use of effectiveness factor is appropriate for first order reaction. However, for 0 to 1/2-order reactions, this factor depended on the bulk liquid concentration and its use may be confusing.

Onuma (Japan) responded that the pressure in the two compartments of the diffusion reactor was balanced. In regard to the relationship between diffusion coefficient and C/N ratio, the interpretation may be that the resistance to pore diffusion at high C/N ratio results in the drop in diffusion coefficient. He also elaborated on the attached biofilm which was grown on a fiberglass filter paper.

Holder (Australia) referred to his early work and Williamson's work to suggest that glucose, and not oxygen, was limiting under the experimental condition reported. He also suggested that a better attached film may be developd by repetition of passing nutrients through the filter and scraping off the slime layer.

B. Paper No. 27: "Scale-up and Limitation of Physical Oxygen Transfer," by B. J. Kim and A. H. Molof (U.S.A.)

Three different laboratory-scale rotating biological contactor (RBC) units were constructed to study the factors controlling oxygen transfer. Physical parameters were identified and evaluated by the volumetric oxygen transfer coefficient (K_La) from non-steady state clean-water tests. The controlling factor was found to be the liquid film flow rate per unit volume. The turbulence effect on the free water surface and subsurface volume became comparatively less significant as disk size increased. Data indicated that physical oxygen transfer contribution to the biological treatment oxygen requirement became less significant than oxygen transfer through other mechanisms as the disk size increased.

Physical oxygen transfer in the RBC system was studied to determine: (1) appropriate scale-up factors, and (2) the source of oxygen. Three laboratory-scale RBC units with 15 cm, 31 cm and 61 cm disks were used. Other experimental parameters were number of disks (N), peripheral velocity of disks (V_p), spacing between disks and rotational speed. A relationship between the oxygen transfer coefficient, K_La, and volume renewal number, N_v, was derived and described in earlier work. The mass transfer coefficient was reported to be correlated to a modified Reynolds number by Ouano (1978). The data obtained in this study indicated that the modified Reynolds number cannot be used for scale-up.

Oxygen transfer in the RBC system can be accomplished from different possible sources. To determine the source of DO, a system was developed for wiping a part of the liquid film from the disks exposed to air. It was observed that the K_La values increased with an increase in liquid film area. Biological oxygen utilization, $(O_2)_B$, reported in earlier work, and the physical oxygen transfer, $(O_2)_p$, reported in this work were plotted against rotational speed. It was observed that $(O_2)_p/(O_2)_B$ decreased as the rotational speed decreased.

The invited discusser, Bishop (U.S.A.), recognized the general omission of oxygen transfer rate for design of RBCs and commended the authors for their work to include this parameter for scale-up. The authors have criticized previous researchers for correlating oxygen transfer rate with rotational velocity and Reynolds number. The dependence of oxygen transfer rate on other parameters such as disk size and spacing was correctly pointed out. The dependence of K_La on volume renewal number (N_v), which includes disk size, spacing and RPM, was validated. However, the data were scattered at high N_v and therefore doubt exists about the use of N_v for scale-up from 60-cm to 1.5- or 3-m diameter disks.

The wiper blade study indicated that little or no oxygen transfer occurred if the disks were dry. The little oxygen transfer that occurred was believed to due to turbulence caused by the falling water. This phenomenon could have been verified by collecting water draining from the disks as done in the study reported by Bintanja. The use of clean flat disks in RBC causes minimum turbulence and provides very little oxygen transfer. In actuality the disks are coated with gelatinous filamentous biofilm which increases roughness. The increased roughness may increase turbulence resulting in an increase in oxygen transfer. He also inquired about the effect of using rough or convoluted disks on oxygen transfer.

It is apparent that disk size influenced the oxygen transfer rate whereas no such effect was noticeable with regard to disk spacing. However, the oxygen transfer rate was reported to be a function of N_v which is dependent on disk spacing. The authors were asked to resolve this conflict.

The results indicated that approximately 55 to 90 percent of the biologically utilized oxygen came from air to biofilm. Ouano (1978) reported that 20-60 percent of the biologically utilized oxygen can be accounted by the direct oxygen transfer from air to biofilm. The authors have also shown that at constant peripheral velocity the ratio of $(O_2)_p/(O_2)_B$ decreased as the disk size increased.

Thus, for full-scale RBC systems the amount of oxygen transferred by physical means will be insignificant in comparison to oxygen directly absorbed by the biofilm. Current research at the discusser's laboratory indicated substantial oxygen transfer into the biofilm from the atmosphere substantiating the findings of Kim and Molof. If physical oxygen transfer is assumed to be a minor factor, then the use of N_v is questionable for design of RBCs. N_v is a practical tool for scaling physical oxygen transfer. But, if direct oxygen transfer to biofilm is the controlling factor, then the RBC design should be based on the exposed surface disk area and oxygen transfer into the biofilm.

Molof (U.S.A.) replied that, regarding data scatter for the plot of K_La at high N_v, he has similar questions about what will happen at high N_v. Collection of liquid to avoid turbulence would have been a better experimental technique, but the experiments presented in the paper were sufficient to obtain information on the relative contribution of the water and air phase. The roughness and types of disk media may affect the oxygen transfer but do not affect the biological growth.

The disk spacing was experimentally observed to affect K_La values. The reasons may be due to use of unmodified or unaveraged S values. In reference to Ouano (1978), he reiterated that this study was the first one to provide quantitative data on the source of oxygen. In reply to the question of the validity of using N_v for design of RBCs, it was pointed out that the work presented is a transitional one to show that oxygen is coming from air and not water.

Harremoes (Denmark) commented on various processes where reaction is limited by oxygen and stressed the importance of oxygen transfer into the biofilm in the RBC system. For example, he mentioned nitrification as the process where reaction in biofilm is oxygen-limited for all practical purposes. He cautioned against the danger of scaling up oxygen transfer rate on the basis of disk area. He questioned the validity of using N_v as the scale-up factor simply because the parameter N_v is not dimensionless. Finally, he inquired if the authors' results have been compared with the results obtained by the theoretical dimensionless analysis reported in the work of Bintanja and Zeevalkink.

Molof (U.S.A.) indicated that according to their earlier work, nitrification was not oxygen limited and suggested that it may be carbon limited. He agreed that normal factors cannot be used for scale-up and expressed his inability to predict whether N_v can be used for scale-up to large-scale system. Although N_v is not dimensionless, this may be the best parameter available, and it gives a better handle of the system. He indicated that the volume renewal number was based on Bintanja's and Zeevalkink's works and their findings were incorporated in the current work.

Watanaka (Japan) agreed with Molof that oxygen in the RBC system comes from the air. If the biofilm is developed on the rotation disks, then the oxygen is transported through the attached layer which exists between the air and biofilm. Thickness of such attached films are determined by the peripheral velocity of disks. However, the air exposure cycle is a function of the rotation velocity. As two parameters cannot be selected for scale-up, he inquired which one of these two parameters, i.e., the rotating velocity and the peripheral velocity, should be used for scale-up.

Molof (U.S.A.) stated that the peripheral velocity is not a scale-up factor and rotational velocity should be used for that purpose.

C. Paper No. 29: "Application of the Marais-Ekama Activated Sludge Model to Large Plants," by H. A. Nicholls (South Africa)

The Marais-Ekama model was used to successfully predict the performance of two 50,000 m^3/d, five-stage activated sludge plants used for nutrient removal. The experimental data used to test the model was obtained by monitoring the feed, effluent and contents of each reactor in the process at two-hour intervals for four days. In addition, a respirometer was developed to measure oxygen utilization rates automatically every 30 min. All data collected were validated with acceptable COD and nitrogen balances across the plants. The data were then compared with the steady state and unsteady state responses of the model.

It was found that the model could successfully predict the COD, TKN, ammonia and nitrate concentrations in the effluent and illustrated some shortcomings in the process layouts. This indicated that the model could be used by designers and operators of large-scale plants to predict performance and highlight problem areas.

The Marais-Ekama activated sludge model has been used on small-scale laboratory and pilot plants where the flow is easy to control and the oxygen utilization rate is easy to measure. The aim of this paper was to predict the performance of actual activated sludge plants using the Marais-Ekama model.

Difficulties were experienced while obtaining a representative sample and while measuring the oxygen utilization rate in both plants investigated in this study. The first plant on which the model was tested was the Johannesburg Goudkoppie plant which treats 150,000 m^3/d. It is a five-stage process in which the first and second stage are stirred reactors followed by an aeration reactor, a stirred reactor and a reaeration reactor. The second plant was the Johannesburg Northern Works plant, which has a design flow of 150,000 m^3/d through a five-stage process. Although the Northern Works plant was similar to the Goudkoppie, its sludge characteristics were slightly different.

The rate of COD and TKN removal predicted by the model were in close agreement with what was obtained in practice for both plants. The oxygen utilization rate measured in the Goudkoppie plant was slightly out of phase from the values predicted by the model. The reason for this discrepancy was believed to be due to the assumption that the aeration basin was a completely mixed reactor whereas in practice some plug-flow conditions do exist. This discrepancy was not observed in the Northern Works plant.

The Northern Works plant was designed to treat an influent COD of 600 mg/ℓ. But in actual practice, the influent COD was found to be only 270 mg/ℓ. Thus, it was not possible to compare the design with the operating conditions. Also, the nitrate in the effluent was extremely high and a portion of it was removed.

In the next phase of this work, the effect of altering the process on the model predictions was studied, but the performance could not be improved at all. The input-data sewage characteristics were then changed and the model performance was examined. This change indicated that the nitrate could be entirely removed by increasing the COD and the readily biodegradable fraction of the COD. The author concluded that if the model is fed with reliable input data, it will predict fairly accurately what is expected to happen in practice.

Ekama (South Africa), the formal discusser, pointed out that it was important to note that the cyclic behavior of the total oxygen demand is satisfactorily predicted in the model. He also mentioned that, at the long sludge age at which the plants were operated (25 days), the variation in the total oxygen demand is considerably damped with respect to the variation in influent oxidizable matter. This aspect being accurately predicted by the model would ensure less power requirement for the aeration equipment in the future. On the other hand, he showed concern on the overprediction of the ammonia concentration in the anaerobic reactor. He also pointed out that like all mathematical models, this model consisted of a number of kinetic constants. The inaccurate determination of these constants might lead to erroneous results.

In replying to the query over the inaccurate prediction of the ammonia concentration, Nicholls pointed out that this was largely due to deflocculation, which is very prevalent in case of anaerobic sludge. The kinetic constants could be determined quite easily and accurately as long as a single-stage small laboratory pilot plant was available. He also agreed with Ekama that in order to operate such complex plants, efficient operators were very essential.

Roberts (South Africa) from the floor posed three questions regarding this paper. He observed that the model lacked authority in predicting the oxygen uptake rates in the two different plants. He mentioned that the oxygen uptake rate does not depend on the hydraulic retention time but is largely dependent on the number and location of the surface aerators and also on the vortex cycling rate induced by the surface aerator. Secondly, he believed that the unbiodegradable part of the influent COD is a function of the solids retention time rather than being dependent on the wastewater characteristics. His third question related to the specific growth rate of nitrifiers as to whether account was taken of the nitrifying organisms that were lost in the effluent from the clarifier.

Nicholls (South Africa) stated phase shift was not observed in both plants. He also commented that the oxygen utilization rate was independent of the location of the probes because the activated sludge is taken in small quantities and pumped into the reactor and then drawn back into the system. With regard to the non-biodegradable particulate matter, it was pointed out that the model measures the biodegradable soluble fraction also, and hence, the effluent content cannot be said to consist of only the non-biodegradable particulate fraction. In response to the question on nitrification, it was indicated that at a long sludge age, little variations in kinetic constants would not affect the predicted values to a great extent.

Beekman (South Africa) questioned whether Johannesburg determined the effect of balancing on the extent of COD reduction obtained in the primary settling tanks. He also wanted to know the effect of varying the mixed liquor recycle ratio. The author stated that flow balancing was achieved in both tanks. The Goudkoppie plant showed a lot of sedimentation in the balancing tank. Due to this settlement, a significant change in COD was observed while the TKN remained unchanged. He mentioned the importance of maintaining the TKN to COD ratio constant while looking into the nutrient removal. It was seen that the COD showed a distinct decrease while the TKN remained unaltered.

Visser (South Africa) inquired on the availability of the model in a simple form to be used efficiently by designers and operators. He questioned the validity of using the mean value of the three oxygen utilization rates in a semi-plug-flow unit. He also wanted to know whether tracer studies had been performed to study the phase-shift-phenomena and suggested the use of CSTR's in series to approximate a plug flow reactor. Nicholls (South Africa) replied that the steady-state response could be used very easily by the operator in designing a plant. Nicholls (South Africa) argued that measuring the oxygen uptake rate at three points was quite acceptable. The oxygen utilization rate was corrected for the oxygen used for nitrification; the oxygen used for denitrification was then subtracted and the oxygen needed for carbon oxidization was thus obtained. This value was balanced successfully with the influent numbers after taking into consideration the losses in the wastewater and the effluent.

Bernard (France) asked about the accuracy in determination of the kinetic constants which would affect the final results. The author said that the kinetic constants can be divided into three groups. Most of them can be classified as those that are independent of the wastewater characteristics. A small group can be found which is dependent on the wastewater characteristics. These constants can be used to find the COD and the TKN needed for the bacteria. The sludge was examined and pilot plant tests were run independently to calculate, for example, the desired COD and TKN concentrations.

Jenkins (U.S.A.) queried whether the model could be relied upon to program aerators to match dissolved oxygen consumption rates in aeration basins. Nicholls (South Africa) indicated that oxygen uptake rates would be looked into as a control mechanism very shortly. He also added that flow balancing together with load balancing would also be studied at a slightly later stage.

D. Paper No. 31: "A Mathematical Model of Biological Purification in Aerated Activated Carbon Biofilters," by G. Martin, A-Y. Le Roux, P. Schulhof (France)

On the basis of results obtained in the laboratory and in a pilot plant, this paper outlined the probable mechanism of biological purification on activated carbon. At low loads, media porosity plays a prominent role in the treatment of a water. The biological activity which develops on the material acts in a complementary fashion, allowing for continuous regeneration of activated carbon pores.

With heavy loads, there are two phases. Initially, adsorption and biological regeneration are complementary. This phase lasts three to four hours. During the second phase, development of the biomass obstructs the occurrence of the absorption phenomenon. This second phase lasts from fifteen to twenty hours, until the filter is clogged. After washing, the first phase again enters into operation.

Preliminary experimental results which led to the development of this work were: (1) Bacteria were present in the macropores and on the edge of meso pores; (2) Approximately 90% of biodegradable materials was found in the bacteria present on the surface; (3) At a low loading rate bacteria were dispersed and did not affect physical adsorption; (4) For the treatment of non-absorbable biodegradable substrates (ethanol), no difference was observed when activated carbon and an inert support media were used; and (5) Bacterial exo-enzymes may be involved in the process.

A mathematical model was formulated to account for the bacterial growth and its migration through the filter, relationship between bacteria and adsorbed substrate and the relationship between bacteria and non-absorbed solute. A numerical solution technique was used to predict the performance of activated carbon biofilters under various experimental conditions.

Activated carbon column experiments were performed using wastewater plant effluent and drinking water spiked with phenols. N, P and other nutrients. The observed effluent COD and phenol values were in close agreement with the values predicted by the mathematical model. The authors concluded that the mechanism postulated for biological removal of absorbable substrated resulted in good prediction by the model. Non-biodegradable substates were not investigated and the authors suggested the use of a supplementary coefficient to account for the residual.

Eden (United Kingdom) noted that for the full understanding of this work, readers need to refer to another paper published in *Water Research* in January, 1982 by these authors on a similar topic. He observed that an aerobic condition in the experimental set-up was maintained by blowing air through the filter--and the process was assumed to be not limited by oxygen. He inquired if any dissolved oxygen measurements were performed to verify this aspect. Also, he pointed out that a few sweeping assumptions were made for the development of the model. These assumptions need to be verified, and the model needs to be validated over a wider range of conditions such as temperature and nature of substrate.

Eden (United Kingdom) asked why phenol concentration in the influent was not constant. It appeared that removal of phenol was fairly constant at a 80 percent level and wondered if this result could have been predicted by a simpler theory.

The researchers appeared to be on less secure ground when they move from soluble substrates such as phenol and methanol to deal with sewage. Assuming that this sewage is settled, no more than 50% of materials are present in dissolved form and the rest is present in suspended to colloidal region. A good portion of this suspended matter is bacteria and bacterial flocs. Much of this bacterial population will be removed by passing through an activated carbon filter. It is unlikely that the mathematical model based on adsorption will fully account for the removal of this nature.

Removal of organic matter from sewage by purely physico-chemical process, even if enhanced by biological means, seems to be unlikely due to unfavorable economics. The reason is that the carbon is to be removed from time to time for regeneration. There could be other applications of biologically active carbon filters, e.g., the treatment of polluted river water with low organics to obtain drinking water. For such treatment biological regeneration of carbon filters may be an economic process.

The author replied that dissolved oxygen concentration in the effluent was verified several times to be rather high--approximately 3-4 mg/ℓ. The variability in the influent phenol was due to experimental problems and was considered desirable. The extension of this model to other processes is under progress to accommodate non-absorbing media. Application of the model to anoxic processes such as denitrification is being contemplated.

In the biological activated carbon filter, it was observed that physico-chemical processes play an important role for the first few hours whereupon biological processes take over and physico-chemical adsorption is diminished. The analogy of this process to the activated carbon process used in water treatment may not be appropriate because of the presence of many non-absorbing materials. In response to the question of removal of suspended particles, it is evident that biological filters do have an important filtering role.

Fleet (South Africa) pointed out that one of the premises that has been used in the model is the mechanism of bioregeneration. It was proposed that the adsorbates migrate into the micropores and then subsequently desorbed out of the micropores during biodegradation. He cautioned against considering such hypothesis even if the model predictions are good because of many simplifying assumptions made for solving the model. Also, he noted that the model predictions are good on a short-term (hours) basis and inquired about the reliability of the model on long-term predictions. Martin stated that, considering the experimental conditions, it was apparent that the substrates did not reach micropores, and the necessity to have access to the micropores was not implied in the model. It is evident that the substrates had access to the meso-pores. The model was tested to predict five-six operating cycles over a period of three months.

IV. CRITIQUE OF SESSION

Paper No. 25 raised questions about the ideal way of developing biofilms for diffusion experiments. Design of the experimental set-up for such investigations is extremely critical for obtaining good data. The critical film thickness of 150 μm should be used with caution as it depends on the substrate concentration.

The results presented in Paper No. 27 answered the basic question of the relative contribution of oxygen by the air and bulk liquid phase. It was shown that the oxygen transfer cannot be scaled-up during disk area or Reynolds number. This aspect of the research has far reaching impact on the design of full-scale RBC systems.

The Marais-Ekama Model for activated sludge process was applied to full-scale processes (Paper No. 29). The model was validated to predict COD and TKN removal in two large plants. Predictions of nutrient removal by the model was poor. The reason for such poor prediction was due to the actual COD and TKN loading being half of the design value. However, if the plants are operated under design load conditions, then the model was capable of predicting nutrient removal.

The mathematical model of activated carbon biofilters (Paper No. 31) postulated a possible mechanism for biofilters. Model predictions were in good agreement with observed values of COD and phenol removal. Extension of the model to accommodate non-biodegradable substrates, suspended solids and temperature would be desirable for wider applications. The model needs to be validated for making long-term predictions.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

None of the studies presented in this session were conducted in sufficient detail to permit direct implementation of the results. However, some direction was provided for future research.

Results presented in Paper No. 25 should be reproduced under well defined experimental conditions and future research emphasis should be placed on the determination of mass transfer through biofilms using complex substrates such as phenol and chlorinated organics.

The results presented by Kim and Molof (U.S.A.) answered some key questions on physical oxygen transfer. This paper was clearly a transitional one. Further work should be continued to determine the ideal scale-up factor. Effect of biofilm, roughness and type of disks on oxygen transfer needs to be evaluated.

Validation of Marais-Ekama model to predict the performance of full-scale activated sludge plants is of great significance for the design and operation of activated sludge plants in this country. The model can be used to pinpoint some of the operational problems in existing treatment plant. Future studies on using this model to determine control parameters such as oxygen uptake rate, flow and load balancing will be of great importance for practicing engineers.

The model for an activated carbon biofilter suggested a probable mechanism of COD and phenol removal. Findings of this study with reference to non-adsorbing substrates have limited the use of carbon filter. Also, the model needs to be validated under various operating conditions such as temperature, types of substrates and particulate matters. It appears that the results of this study may not be of any practical use at this time without future research.

I. SESSION

A. Day: Thursday, April 1, 1982
Hall: B
Time: 9:00 a.m. to 1:00 p.m.

B. Theme of Session: Physical/Chemical Waste Treatment and Metal Removal

II. REVIEWER

A. Name: David Jenkins

B. Position and Affiliation: Professor of Sanitary Engineering
University of California
Berkeley, CA

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 33: "Granular Activated Carbon and Preozonated Granular Activated Carbon Treatment for Biologically and Physically-Chemically Treated Wastewater Effluents," by A. Netzer and J. L. McNutt (U.S.A.)

This paper described pilot-plant testing of activated carbon column treatment of both biologically treated, physical-chemical treated and mixed biologically plus physical-chemical treated effluents. Results with and without preozonation of effluents were presented. Improved treatment efficiency and extended carbon life were obtained for preozonated effluents. Much more data (additional parameters and extended periods of performance) were presented. The author indicated that optimization of column loading and ozone dose were being investigated currently.

In the realm of activated carbon studies, this paper could be classified as applied research that investigated the effect of a pretreatment step on performance in terms of gross parameters such as BOD, COD and TOC. It was pointed out that for all these parameters, the prototype plant performed significantly better than the pilot plant (e.g., BOD removal: pilot plant 39%, prototype plant 31-86%; COD removal: pilot plant 25%, prototype plant 43-63%). These significant differences raised questions as to the true similitude between the pilot plant and the prototype designs. The effluents treated by carbon were very high in suspended solids (SS) due to the poor performance of the prototype treatment plants. Discussions raised the question of the effect of SS on the experiments. While no specific response was given, the author noted that initially the carbon columns were backwashed with air scour four times daily. Later, sand filtration was used prior to the carbon columns. Agreement with the author's reported benefits of preozonation was voiced by workers from the Daasport pilot plant in Pretoria, South Africa. They are, in addition to preozonation, studying Cl_2 pretreatment, optimization of preozonation and the use of aerobic carbon columns. Swiss work showed an even greater benefit for preozonation in treating water for potable uses: with no preozonation, regeneration was required in five months, while with preozonation, columns were regenerated once every three years; only 12% carbon loss had been experienced in six regenerations.

B. Paper No. 35: "The Nature of the Reactions Between Chlorine and Purine and Pyrimidine Bases: Products and Kinetics," by J. G. Gould and T. R. Hay (U.S.A.)

This paper was an investigation into the rates and products of reactions of chlorine with three nitrogen-containing heterocyclic bases, i.e., uracil, cytosine, and caffeine. Reactions of chlorine and these bases were found to differ significantly in rate and nature of products. Caffeine yielded a complex array of ring cleavage and rearrangement products in a relatively slow reaction. True ring chlorination with the production of 8-chloro-caffeine occurred in these systems but was relatively minor process. The reaction was fairly slow, high-pH dependent, and yielded an array of labile combined-chlorine species and chloride. Chlorine species analysis gave little evidence of the formation of carbon-chlorine bonds. Uracil reacted rapidly with chlorine undergoing considerable true chlorination with the formation of a product consistent in character with 5-chlorouracil. Kinetically, the reaction was strongly pH dependent. While small quantities of chloramines were produced, they were labile, arising most likely as a result of ring cleavage. Cytosine produced a complex array of products including chromatographable organic chloramines. Fifty percent of chlorine added to cytosine was manifested as combined chlorine of high stability. Evidence for various N-chlorocytosines was presented.

The author expressed caution in extending results of chlorine reactions with one compound to other compounds of similar composition--for example, the reactions of chlorine with cytosine are quite different from those with 5-methylcytosine. However, the author stated that it would not be necessary to study reactions with every single organic nitrogen base since, with the accumulation of more data on such compounds, some ability to predict such reactions may become evident. The toxicity of the products was not well known--Ames testing showed weakly positive mutagenic effects but the author cautioned that false positive results with Ames testing could not be discounted. The inability of wet chemical methods for determining chlorine in forms such as 8-chlorocaffeine was noted. Such methods lump these chlorinated organic nitrogen compounds into "dichloramine active" substances; amperometric methods are unsatisfactory because of the unreactivity of these materials. Gas chromatographic analysis of reaction products gave the same result as the milder thin-layer chromatographic techniques and thus the products did not decompose under the gas chromatographic conditions employed. The author suggested that the chlorinated organic nitrogen compounds formed would be readily reduced by sulfur dioxide under conditions representative of wastewater dechlorination.

C. Paper No. 37: "The Fate of Some Metal Species: Lead, Cadmium, Zinc in Surface Water During Biological Sand Filtration--Effect of Preozonation," by F. Erb, D. Delabre, J. C. L. Hopitault, A. Philipo, P. Thomas and A. Brice (France)

Slow sand filtration of raw water reduced its metal contents with up to 50 to 60% reduction being obtained for Cd and Pb. Preozonation solubilizes particulate Cd and Zn and breaks complexes of metals with organics such as humic material and converts them to free metal ions which then are eliminated more readily. Preozonation provides for a greater efficiency of metals removal by sand filtration than does flocculation.

Discussion centered around two issues. First, several points on experimental validity were raised--the limits of metal detectability by the techniques used were questioned; the loss of metals between their addition to feedwater and dosing on to the sand columns was pointed out and the author agreed that precipitation and adsorption onto vessel walls could occur; the question of changes in metal speciation in the five days between addition to feedwater and use in experiments was raised; the validity of using 0.45 μm membrane filters to differentiate between soluble and particulate metals was questioned; there was agreement between a discussor and the author that preozonation could liberate metals from organic complexes and lead to better removal in a sand filter however. Perhaps ozonation could could also lead to higher biodegradeability, a better flow in the sand filter and therefore a better removal of metal.

The second issue of discussion was raised by the observation that the authors' experiments were conducted on metal levels lower than those stated in the European Economic Community (EEC) Directives on water for human consumption. Points raised were: why conduct such a study if the metal levels are already acceptable? The EEC directive is a maximum, and we should try to do better. We should not waste money in trying to achieve quality better than the EEC directive. All parts of the EEC directive are not mandatory, but governments must take the EEC directive into account when setting their own standards, which may be more stringent than the EEC directive. The EEC directive and other standards are maximum allowable values, not the most desirable; scientists should conduct research to produce water of better quality. The matter was unresolved.

D. Paper No. 39: "A New Configuration of the High-Lime Process with Sludge Recirculation for Magnesium Recycling," by E. Idelovitch and A. M. Wachs (Israel)

The paper described a process for magnesium recycling in the lime treatment of oxidation pond effluent for phosphorus removal. A portion of the sludge produced was dissolved in treated effluent. The effluent, which was enriched with Mg, is recycled to the lime addition unit. The modified process results in more readily dewaterable sludge [i.e., it contains less $Mg(OH)_2$], elimination of need to add supplementary $MgCl_2$, and reduction of lime dose to reach a given high pH value. Accumulation by dissolution and recycle of potentially harmful materials such as heavy metals and boron does not occur to a significant degree.

Several points relating to the process engineering aspects of the proposed scheme were raised (e.g., effect on sludge thickening, effect on solids loading of solids handling devices, need for equilibrium studies especially in view of classification of solids that takes place in centrifuges, cost comparison with recycling). The author indicated that such matters would be addressed in future pilot plant work.

The author agreed with a discussor from South Africa that Fe (II) addition could be used as a flocculant instead of Mg in the high-lime process but indicated that their waters were hard and had a high alkalinity so that it was beneficial to use the Mg available in them. Quoting experience with the use of CO_2 regeneration of lime sludge from a low pH lime treatment of water, a discusser from South Africa indicated increases of organic matter in the water released from the sludge that was eventually recycled to the treated water to increase the organic content of the effluent. The author stated that in his system, a secondary polishing pond was available; and in addition, he believed that the use of high pH in the lime precipitation process improved organic matter biodegradeability in the secondary ponds. The author indicated that these secondary polishing ponds also served as recarbonation basins; no problems had been encountered in them due to $CaCO_3$ deposition. After a period of several years, only a few millimeters of $CaCO_3$ has been found on the bottom of the ponds.

IV. CRITIQUE OF SESSION

These papers varied greatly in approach, application and quality. Two (Papers No. 33 and 39) were strictly applied investigations, one was a strictly mechanistic study (Paper No. 35), and one a laboratory investigation of process performance (Paper No. 37). Paper No. 33 was of limited applicability because of its empiricism; Paper No. 37 also was of limited value because of questions of methodology. The basic information on chlorination of organic nitrogen bases presented by Gould and Hay was of high quality and should be viewed as the first step in the right direction down the difficult road to understanding the chemistry of these processes. Paper No. 39 contained material of merit but left unanswered many questions of feasibility and economy that will have to be answered by future pilot plant work. Papers No. 33 and 37 emphasized the potential value of preozonation as a process for improving the performance of organic carbon and also in aiding metals removal by biological and (slow sand) filtration. Its use in both potable water treatment and in the tertiary treatment of wastewater effluents is deserving of further study.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The significance of the papers presented in this session is somewhat limited: the two points that stand out are (1) the value of ozonation as a treatment process prior to activated carbon (The extent of the benefits of this process and the mechanism of changes that take place during ozonation and subsequent treatment by carbon need to be studied in depth.) and (2) the complexity of the interactions between chlorine and organic nitrogen compounds typical of those found in treated wastewaters and waters. Further fundamental investigations along the lines of that reported in this session are deserving of support.

I. SESSION

A. Day: Thursday, April 1, 1982
Hall: B
Time: 2:00 to 5:00 p.m.

B. Theme of Session: Wastewater Treatment

II. REVIEWER

A. Name: Foppe B. DeWalle

B. Position and Affiliation: Associate Professor
Department of Environmental Health
University of Washington
Seattle, WA 98195

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 41: "An Integrated Low Cost System for Treatment of Potato Processing Wastewater Incorporating Anaerobic Fermentation and Phosphorus Removal," by J. G. Parker, B. J. Lyons, and C. D. Parker (Australia)

Anaerobic fermentation was used to treat potato processing wastewater with a BOD of 48,000 mg/ℓ followed by 350 mg/ℓ lime treatment for phosphorus removal of the combined effluent and the low strength wastestream. After 0.350 ℓ/min pilot plant studies, a 1362 ℓ/min full-scale plant was started beginning in 1980 and gave BOD removal efficiencies of 89% as compared to 93% for the pilot plant. The wastewater was suitable for discharge to the domestic sewer. Both the pilot and full-scale plant gave gas production of 390 ℓ gas/kg BOD removed with 55% of the gas consisting of methane at a BOD load of 6.6 kg BOD/m^3. The full-scale anaerobic digestor had a 6.9-hydraulic detention time, a sludge age of 50 days and MLSS of 25,000 mg/ℓ. The final plant effluent met all sewer discharge requirements except for organic nitrogen (51 mg N/ℓ). The mud and phosphate sludge was disposed of on potato-growing land.

B. Paper No. 43: "The Adsorption Behavior of Cationic Polyelectrolytes in Dissolved Air," by R. Gehr and J. G. Henry (Canada)

The effectiveness of cationic polyelectrolytes with a $FeCl_3$-conditioned activated sludge in a dissolved air flotation system was evaluated with respect to molecular weight and ionic charge. The tests were conducted with 2100 mg/ℓ of MLSS and 115 mg/ℓ of O_2. The 2 x 10^6 MW and the 10 x 10^6 MW polymer resulted in a thickening parameter of 1300 and 1200, respectively, an effluent SS of 27 mg/ℓ and 24 mg/ℓ, repectively, and an extrapolated monolayer coverage of 4.3 mg/g and 7.4 mg/g, respectively, during batch testing. The greater degree of adsorption of this high molecular weight polymer reflected its greater extent of looping of segments into the solution. The minimum effluent SS were reached at a coverage of 3.5 mg/g for both polymers, corresponding to a polymer residual of 0.5 mg/ℓ and 1 mg/ℓ for the high and low MW polymer, respectively. Higher polymer dosages did not further reduce effluent SS but increased the thickening parameter resulting from the displacement of water from the floc by air bubbles. The zeta potential changed from -16 to a positive value at the first appearance of polymer residual in the solution. An extrapolated monolayer coverage of 17.2 mg/g was obtained for the full-scale testing of a 8 x 10^6 MW polymer with a cationic charge 30% lower than the polymers used in the batch tests.

C. Paper No. 45: "The Performance of an Ultrafiltration Pilot-Plant for the Closed Loop Recycling of Textile Desizing Effluents," by C. A. Buckley, R. B. Townsend, and R. Groves (South Africa)

The author described the first 16 months of spiral wound membrane ultrafiltration pilot plant testing to recover the polymer PVA from 25% of the 75°C desizing effluent of a cotton mill. The 18,000 MW spiral ultrafiltration membrane concentrated the 10^6 MW PVA from about 20 g/ℓ to 60 g/ℓ after which the retentate was reused in the sizing operation, while the permeate was reused in the washing operation. The total PVA loss during each recycle loop was 25% which has to be replenished through makeup to bring the retentate concentration from 60 g/ℓ to 80 g/ℓ. The desizing effluent had to be pretreated by either filtration using a 10 μm candle filter or centrifugation to remove short fibers that otherwise would block the feed spacer mesh. As a result of the recycle, the COD load was reduced by 900 tons/year and the unit paid for itself in approximately 1.25 years.

D. Paper No. 47: "Leaching Characteristics of Industrial Metal Finishing Wastewater Treatment Plant Solids," by T. H. Goodgame and P. W. Barnett (U.S.A.)

Metal phosphating and pickling sludges generated during lime precipitation were placed 20-29 cm deep in a lysimeter and leached with distilled water at a rate of 510 cm/y. Maximum initial concentrations of 812 mg/ℓ COD; 590 mg/ℓ Na; 432 mg/ℓ Ca and 2050 mg/ℓ SO_4 were noted at pH values ranging from 7.1 to 9.2 with sulfate and iron exceeding drinking water standards. The simulated 10-year landfilling of the sludges resulted in a maximum leaching of 64% of the calcium (sample A) and 63% of the sulfate (sample B), while less than 1-6% of the metals were leached.

IV. CRITIQUE OF SESSION

Paper No. 41. Alternative product recovery schemes such as starch recovery by ultrafiltration or waste conversion to yeast for cattle feed were not evaluated. The plant used the wet peel method for skin removal; however, much lower waste loads are generated by the dry mechanical peel method. Although the latter method is more expensive, the lower wastewater treatment costs often make the combined process cheaper.

Paper No. 43. Adsorption was expressed in milligrams instead of moles. As the high molecular weight polymer has five times greater weight than the low molecular weight polymer, the adsorption of the former is much lower on a molar base. The use of the Langmuir isotherm is questionable as the looping is in obvious conflict with the postulated complete monolayer coverage. It is, therefore, better to use Henry's constant at infinite dilution or to use the Freundlich isotherm. Insufficient data are given for a comparison of the bench-scale batch testing and the full-scale continuous testing with respect to effluent SS and sludge thickening. In addition, the continuous testing used a polymer not evaluated during batch testing.

Paper No. 45. Many critical data are missing from this paper such as the flowrate during pilot-plant testing, the membrane surface area of the pilot plant, the volume percentage permeate of the overall unit and of each of the three stages. The data in Fig. 1 do not distinguish between different recycle flowrates and temperatures, the data in Fig. 2 do not distinguish between different recycle flowrates, and the data in Fig. 3 do not specify temperatures. Were all these data generated for a single module or for the tapered series in batch or continuous mode? The data in Fig. 3 do not include the 0% PVA line for a clear membrane using tap water to determine whether it has a similar flux shape as the 0% wash water line. No data were given of the long-term flux decline during the 16 months of operation. What was the percentage downtime during this period? The washwater rate is given per kg of cloth while other parameters are expressed per meter of cloth. The PVA mass balance does not close. As much as 25% of the PVA is lost during each cycle with 6% of the PVA remaining in the cloth, 10% of the PVA removed in the filtration/centrifugation and 9% unaccounted for. As a result of the closed loop, the water use was apparently reduced from 3 m^3/h by 29% to 2.2 m^3/h; however, sizing usually represents only about 40% of the plant flow. The COD was apparently reduced by 900 tons/year; what was the COD of wastewater before and after recycling? As a result of the recycling, a gradual buildup of the soluble COD in the retentate is expected: how much was it and did it influence the quality of the washed cloth? The pilot unit was apparently designed for a 5 ℓ/m^2·h flux rate (0.75 m^3/h with 150 m^2) while the full-scale design used 7.4 ℓ/m^2 . h (3 m^3/h with 405 m^2); what was the rationale for this? Why was the full-scale unit operated in a batch mode instead of designing for fewer elements and using a continuous mode? What was the tapering design for the full-scale unit?

Paper No. 47. The major criticism of this study was the use of distilled water instead of a simulated leachate with a high concentration of acetic acid and a pH of 4.0-5.0, as is often found in a young landfill. Under these conditions much higher metal concentrations would have been leached out initially. Anaerobic instead of aerobic conditions should have been selected, resulting in the reduction of sulfate to sulfide, which in turn would precipitate several of the heavy metals.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Paper No. 41. The paper described the first integrated plant of its kind in the potato processing industry based on separate treatment of high-strength waste with energy recovery and low-strength wastestreams for phosphorus removal. Many plants in the United States combine wastestreams for joint treatment thereby greatly reducing the potential for energy recovery. Due to energy savings, this process was considerably cheaper than conventional spray irrigation requiring 240 hectare and anaerobic/aerobic lagoon treatment requiring 60 hectare, as often used in the United States. The studies showed that 4000 mg/ℓ of sodium and 5000 mg/ℓ of fatty acids were not toxic while 10 mg/ℓ of sprout-inhibitor (chlorophenyl isopropyl N-3 carbonate) was toxic to the anaerobic fermentation at an average pH of 7.4.

Paper No. 43. The study provides a model to interpret dissolved air flotation (DAF) data. As the DAF process requires as little as 10 min, compared to 1-3 hours for conventional gravity thickening, a much smaller-sized unit can be selected resulting in a lower cost. A DAF process should be evaluated as an alternative for difficult-to-settle sludge, as much smaller sludge flocs are still acceptable. The limitations of DAF are the ability of the small air bubbles to attach to the sludge floc and the necessity to use polymers to provide a sufficiently strong floc. Since all tests were done with sludge conditioned with $FeCl_3$ to provide phosphorus removal, less positive results could be expected with regular activated sludge.

Paper No. 45. Despite the missing information, the paper showed that reuse of sizing polymers is possible using membrane ultrafiltration resulting in the elimination of the washwater stream often accounting for 40% of the total wastewater stream and 65% of the COD load. Since energy costs are generally higher in South Africa than in the United States, the payback time should even be less than the estimated 1.25 years.

Paper No. 47. This study has no major significance to the United States metal sludge disposal practices, as unrealistic leaching conditions were selected. This opinion was shared by most participants of this session.

I. SESSION

A. Day: Friday, April 2, 1982
Hall: B
Time: 9:00 a.m. to 12:30 p.m.

B. Theme of Session: Sludge Treatment and Disposal

II. REVIEWER

A. Name: Alan H. Molof

B. Position and Affiliation: Associate Professor
Department of Civil and
Environmental Engineering
Polytechnic Institute of New York
Brooklyn, New York

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 49: "Aerobic Thermophylic Stabilization of Sludge versus Anaerobic Digestion and Other Kinds of Sludge Treatment at Middle-Sized Plants with Respect to Power Conservation and Economy," by P. Wolf (Federal Republic of Germany)

The paper covered a comparison of aerobic thermophylic stabilization (ATS) and anaerobic digestion with gas recovery (AD) for medium-sized wastewater plants in the Federal Republic of Germany. The temperature of 2 open parallel ATS reactors on a once per 2-day feeding schedule ranged from 25 to 38°C in winter. The higher temperature of a 2-stage ATS covered reactor system was 35-40°C in the first reactor and about 50°C in the second reactors. The air temperature was about 10-12°C. A temperature record for the whole year ranged between 30 to 50°C.

The open reactors had a volume of 75 m^3 and were fed 18.5 m^3/d on alternate days. The sludge was a mixture of primary and secondary sludges thickened to about 4% solids. The detention time was 6.9 days.

Characteristics of a well stabilized ATS sludge were less than 100 g/kg VS·d for specific rate of O_2-respiration; less than 5 g TPF/kg VS for enzymatic activity; less than 35 g/kg SM for ether extract; greater than 10 days for lead acetate test; and less than 10 s/g SM for capillary suction time (CST). The two open parallel ATS digesters differed in performance although both had 2.7% solid matter, one had 61.3% volatile matter and a pH of 7.8 while the other had 61.8% volatile matter and a pH of 8.3.

The energy factors of the ATS open reactors were listed as energy input at 85 W/m^3 of usable reactor volume and energy consumption at 18 kWh/m^3 of thickened raw sludge. The air rate used for oxidation was minimized to conserve heat loss. The operating temperature was found to be a function of the total sludge solids, tank insulation and the air rate. The open reactors exhibited a scum layer of about 0.5 m which acted as an insulator.

Data on energy cost, running cost, capital cost and annual cost were presented in graphical form for various sludge processes. These included open digestion, aerobic thermophylic stabilization, raw sludge dewatering, combined aerobic stabilization, and heated digestion with no gas, with heating and with power generation. A summary of the cost data is as follows:

(1) For a plant with about 20,000 population equivalents (PE), open digestion and the ATS process produce equal and the lowest annual costs. The combined aeration stabilization (CAS) process costs are markedly higher and are equal to the AD process without use of digester gas. The annual costs increase with the use of digester gas for heating and power generation.

(2) For plants of 50,000-100,000 PE, the ATS process costs approximately equal the AD process costs. At 50,000 PE they are more economical than the CAS process due to improper power splitting in aeration to meet the differences in oxygen consumption for day, night, weekday and weekend operation.

(3) At 250,000 PE the AD process with or without gas utilization is the most economical.

The nominated discusser, Bernard (France), stated that the process cost comparison can be a hazardous exercise. He stated that ATS process uses more energy than the AD process. There is government encouragement toward energy recovery even though it is often not based on economics. He stated that it is difficult to accept long-term storage for the ATS process and asked if there was information on pathogen levels in the series ATS process in summer and winter and if it can be compared to the AD process. It was noted that there are substantial differences in energy recovery and asked: What is the explanation of differences between raw influent and raw sludge?

He said that ATS is more vulnerable than AD and that the choice between ATS and AD is not all that obvious. He noted that AD can give energy independence while ATS cannot.

The author replied that it was found that it was only possible to reclaim 30% or 1.9 kWh/m^3 digester gas, although manufacturers speak of reclamation of heat as 47% of the energy input. He agreed with the comment on government encouraging energy conservation. In small plants, he noted that there is no problem with the ATS process. However, sludge can be stabilized by storage in open ponds for six months.

Matthews (United Kingdom) stated that sludge treatment should never be considered without including sludge disposal. He raised points: (1) What is the volume per PE produced after final thickening for the ATS and AD processes? If the ATS produced more sludge, then cost of transportation would rise; (2) It is important that sludge quality be taken into account. For example, if ATS has a higher pathogen level, the sludge would be less acceptable in agriculture, and increased constraints in disposal would increase disposal costs; (3) The author was asked to comment on the fact that the ATS sludge will have less free ammonia than AD sludge. This would result in less acceptability as a fertilizer and thus increase disposal costs.

Beekman (South Africa) asked three questions on the utilization of digester gas for power generation or direct drive to a compressor. These were: (1) Is the gas pressurized for all plants or is there a mixture of pressure and nonpressure? If so, what is the pressure being used for the machines?; (2) What is the machine type? Is it based on pure gas or a mixture of gas and fuel oil? If so, what is the percentage of fossil fuel used?; (3) What is the average size of the generator?

The author replied that ATS sludge is higher quality than the AD sludge due to higher temperature operation. If the detention is six to eight days and the temperature is greater than 50°C, one could assume that there would be no practical problems as concerns bacteria. At high temperature, there will be no ammonia oxidation. Utilization of digester gas works with normal pressure vessels. Usually the engine is gas driven. There are very few cases where the gas-fuel oil is used.

B. Paper No. 51: "Simultaneous Pasteurisation - Digestion (SPD- Process)," by G. Kugel (Federal Republic of Germany)

The author stated that the object of the simultaneous pasteurization-digestion (SPD) process is a safe and robust process using digester gas with adequate pasteurization by submerged combustion heating. The advantages of submerged combustion heating were indicated to be: (1) spontaneous heat exchange; (2) high degree of contact between gas and liquid; and (3) high efficiency due to heat recovery. The disadvantages were indicated to be: (1) flue gas deodorization; and (2) application only for large plants when using a digester gas supply.

The wastewater treatment plant for 100,000 PE (population equivalents) consisted of primary and activated sludge processing. The digester gas from storage was used to provide the fuel for the submerged combustion heating. The flue gas was passed through a compost filter for deodorization. The sludge was heated to 80°C in winter and 85°C in summer and digester temperature was 35-38°C. Cooling water for the heated sludge at 80-85°C was from the secondary settling tank effluent. Energy sufficiency was only reached in the SPD process, not in post pasteurization.

A question has been raised concerning the effect of the high heat of pasteurization on the sludge. Although Lipmann has shown little effect in the laboratory, there is still a question if the sludge is affected. The wastewater contained a majority of potato-processing waste high in organic material, i.e., starch. The volatile solids in the influent were 35 kg/m^3 and were 14 kg/m^3 in the effluent, or 60% digestion efficiency. To improve the digestion process, it is proposed to try $FeSO_4$ to improve the thickening step. The volatile acids were low at about 70 mg/ℓ during peak potato processing in the spring. The median gas yield during the winter peak was about 28 m^3/m^3 sludge with a 90/10 probability ratio of about 1.45.

The SPD process yielded sufficient gas to avoid purchasing outside energy. In 1980-81 the calculated gas surplus was 30.5 percent, even with the equipment not at an energy optimum. For the future one could expect flue gas-gas engines or turbines.

The nominated discusser, Baines (United Kingdom), stated that the use of the term "simultaneous" is difficult to understand since pasteurization actually precedes digestion. Perhaps "sequential" would be a better word and still retain the initials, SPD.

The crux of the matter is the pressure for pasteurization. Is the pressure coming from the government as indicated in the Federal guidelines of 1972? What is the present situation in Germany, i.e., is pasteurization recommended for land application or could another method, such as irradiation, be used?

The SPD process does not prevent recontamination during storage and before land application. The effect of the SPD process on the most important pathogens is not included. Could the author provide information on bacteria, parasites such as tape worm and others? The enterobacteria densities are given only at the beginning and end of the five-month operation. Could information be provided for various points in the process before and after pasteurization, after digestion, and after storage before land application?

During the pasteurization it could be presumed that methanogenic and other bacteria would be greatly reduced. The remaining bacteria are seeded by the digesting sludge and the count increases rapidly during digestion to provide a good seed sludge. The bacterial status of the digestion is of interest, i.e., do the surviving methane bacteria increase partially due to reduced competition? This may partially explain the high gas yield or could this be due to the potato starch itself? If due to the potato starch, then the results would be similar if post pasteurization or digestion alone were used.

Several points were cited: (1) How is the digester heated? The cooling water is not used; (2) The input sludge temperature is controlled in a narrow range, yet a temperature range of 28-70C is quoted; (3) The loss of energy in the cooling circle will be improved as indicated.

The tabulated energy of the water and sludge pump indicated that 45% of the energy (28% sludge and 17% water) was consumed in the cooling circle. If the cooling water is not used, then the energy is lost. However, the heat dissipated in the digestion-pasteurization process requires no cooling water and therefore saves energy.

In summer the starch would be lower and gas would be reduced. Could the extra energy required be justified compared to the digestion-pasteurization process or the pasteurization processes such as irradiation?

Pasteurization before and after digestion has been tried at the Cape Flats Wastewater Treatment Plant in Capetown. Could someone comment on this experience with a less specialized sludge?

The author replied that he accepted the term "sequential" in place of "simultaneous" and agreed it was a better term. During the last 10 years, he stated that certain regulations have been made by the government for removal of parasites from sludge before disposal on land. Presently, the government is preparing legislative revisions which will be published before the end of April (1982). These regulations or guidelines will state that no sludge can be put on pastures or fields without pasteurization and will be effective in 1986. Sludge disposal on agriculture land will require an effective public relations image. Other pasteurization methods are permitted. For example, Co^{60} irradiation is in operation. However, this use is troublesome to the general public.

Results of Breer in Switzerland indicate that after the submerged combustion heating, there were $10^2/m\ell$ of enterobacteria. This was also the count with effluent. Parasite eggs are killed off below the operating temperature. Based on these counts, if confirmed, there is no need for final storage facilities to be covered. Post pasteurization is okay. However, it is significantly worse than prepasteurization. A gas yield of only 15 m^3/m^3 was obtained with an automated system. Operation was more difficult and costly. After three-five months, the enterobacteria count stabilized at $10^2 - 10^3/m\ell$.

Beekman (South Africa), in floor discussion, stated that Cape Flats, the first large-scale plant using pasteurization in South Africa, has only just started up. The plant has sufficient digester insulation and heat transfer area to maintain the proper digester temperature.

At St. Galons, Switzerland, he observed similar results as presented here indicating that pasteurization before digestion gave much better results. It is of interest to note the large increase in gas of 15-25%. Other pasteurization plants were observed in Switzerland that were inoperative, possibly due to having pasteurization after digestion. Most of the material disposed has been in the liquid phase. Does the author have an experience in the dewatering characteristics of the final product?

Coker (United Kingdom) stated that an important principle which has been stated by the author is to have requirements for sludge treatment which consider the final disposal method and thus produce a sludge fit to use, i.e., use in agriculture requires pasteurization. The results presented are in line with results with partially pasteurized agriculture and horticulture soils which get markedly increased mineralization following heating to 55-60°C. What would be the percent increase in cost to add the pasteurization step to an existing digester plant?

Schlegel (Federal Republic of Germany) stated that heating to 80° causes a large degree of hydrolysis and improved dewatering, thereby indicating pretreatment by pasteurization is desirable. This was only shown last year in Japan at the Second Anaerobic Digestion Conference.

Is it possible that the surplus gas was due to starch waste and not necessarily due to the domestic portion? What was the wastewater influent BOD and COD?

The author answered that recycling or agricultural use is done in the liquid phase. About 25 years ago, artifical dewatering was tried and abandoned. There is no experience on drying. The additional cost for post pasteurization in 1971 was 5.5 million DM.

He agreed that the high gas yields were due to starch. The potato season ends in May with nothing in May and June. The gas yield at the time is much lower at 15 - 18 m^3/m^3 sludge. During holidays there is poor operational performance under these nonideal conditions. It is ideal only during the potato season.

C. Paper No. 53: "Inhibition Modelling in Anaerobic Digestion," by A. C. Duarte and G. K. Anderson (Portugal and United Kingdom)

Sludge digesters have failed in the field due to some type of inhibition, and there is an interest in defining the conditions responsible for these failures. Andrews (U.S.A.) has proposed a comprehensive theory that it was the effect of the substrate, volatile acids, which were inhibiting the activity of the methane bacteria. There seemed to be some doubt as to whether the inhibition was due to the substrate itself or whether it was the effect of the volatile acids reducing the pH. The aim of the work was therefore to test the inhibition theory of Andrews.

The work was carried out with 25-ℓ anaerobic contact digesters. At this size, there has been some difficulty in interpreting the data due to buildup of growth on the walls of the reactor. The digesters were fed in two ways, i.e., sodium acetate was added to stimulate methane production and glucose was added to produce volatile acids. When the digester wall was scraped, failure conditions were more easily reached. At constant feed, the pH decrease resulted from increased acetic acid loading. When the pH dropped from 6.5 to 6.3, the methane production was reduced by 65% and acetic acid level increased from 750 to 1500 mg/ℓ. At a pH of 7.6, the increase in acetic acid of 750 to 1500 mg/ℓ showed no inhibitory effect. This suggested that inhibition could be controlled by pH.

Other variables such as hydraulic retention time (HRT) were tested. At the same HRT, a higher pH gave a higher COD reduction, i.e., a 10% difference. At different HRT and at constant pH, the effluent COD values were the same. This confirmed that Monod kinetics was not a good model for the methane phase.

Under good operating conditions acetic acid was the primary volatile acid formed. But as the pH was allowed to drop to 5.5, a high proportion of the acids formed were propionic and butyric. If the digester was allowed to stand, the pH slowly increased, the CO_2 slowly recovered and the methane production remained low until the pH was 6.4. This recovery was partially due to the wall growth. The implication is that if the pH is greater than 6.5, inhibition will not take place in a carbohydrate-rich reactor if other inhibitory agents are not present. Inhibition did occur with high unionized volatile acid, irrespective of the pH. It thus appeared that inhibition was due to a mixture of volatile acids and pH.

Other work was done with anaerobic filters with much higher wall growth. There appears a wider tolerance range for the pH-substrate combination and therefore, a more robust system than the anaerobic contact digester.

Other observations included the formation of propionic acid which is not significant in normal operation. However, if the digester failed, the propionic acid produced appeared to limit the rate of recovery. Propionic acid appeared to have some role in the recovery of digesters after failure.

The final point is not in the paper. Recent work has been done by Anderson on ammonia and sulfate toxicity. Sulfate problems are due to (1) sulfate toxicity, (2) corrosion of gas burners, and (3) 10% reduction in methane production. A simple solution based on nutrient control has been tried which prevents inhibition of methane production and plant corrosion due to sulfide.

The nominated discusser, Marais (South Africa), stated that he did not believe that the paper, containing lots of information, was written in a clear and understandable manner and that the values hidden in the paper should have been brought out more clearly. He stated that the object of the paper was to apply Andrew's equation on growth rate inhibition using acetate and glucose substrates.

Andrew's equations are in terms of the undissociated acetate species. Since the undissociated acetate species is related to the total acetate concentration through the pH and pK values for dissociation of acetate, the use of the equation is not straightforward. The authors did not deal with this aspect presumably since they assumed it was weak acid-base chemistry. An explanation from the authors would be valuable on how they dealt with the interaction between undissociated acetate and free acetic acid.

The authors used the Monod equation with a factor for inhibition included. The substrate concentration was the undissociated acetic acid, not the total acetic acid concentration. For a plot of the equation versus total acetic acid concentration, the fraction of undissociated acid would vary at every pH. If a K-inhibition value was assumed, the plot of growth rate versus the undissociated acetic acid concentration would rise and fall, unlike the Monod equation which rises and levels out. In addition, this plot would change for every pH.

If at a specific growth rate, i.e., the independent variable, a line is drawn horizontal to the concentration axis, it will intersect the curve at two points. The first crossing indicates stability and a tendency to equilibrium, while the second crossing indicates a failure tendency even though both are at the same specific growth rate. The authors took these concentration values and interrelated them with the concentration expressed as total acetate for various pH values. The line separating stability and instability zones in the paper represented 10 mg/ℓ of undissociated acetic acid and was supported from other information. In terms of the authors' theory, even though it is a parametric approach, it provides information on why the digesters failed, which the discusser considered an interesting contribution.

However, one must bear in mind that the inhibition effect shown by the equation used is empirical and not based on any biochemical mechanism. Also, the transition from an unfailed to a failed reactor will be associated with a changing pH and acetate condition, and it is not evident which of these values should be plotted on the diagram. Furthermore, as pointed out by the authors, the data in the healthy digester area does not consider failure due to washout.

In the propionic acid studies, the authors consider that propionic acid breakdown was the rate-limiting step in the methane fermentation of substrates such as glucose. This phenomenon has also been observed by other investigators. However, it has long been thought that short chain fatty acids are broken down by at least two organisms symbiotically. The one species breaks down propionic acid to acetate, carbon dioxide and hydrogen and is considered to be inhibited by the hydrogen. The second species, a methanogenic organism, breaks down the acetate to methane and carbon dioxide and also combines the carbon dioxide with the hydrogen to form methane. This implicates hydrogen as an important intermediary.

The author replied that the growth equation will lead to two solutions as referred to by Marais. In the lower solution will be the stable region, and in the upper region, the region past the maximum growth rate, is in the unstable region.

Concerning the propionic acid, no comment was made except that the thermodynamics and biochemistry are at present unsatisfactory and more work is needed.

Spies (Federal Republic of Germany), in floor discussion, stated that in the anaerobic contact process, one cannot control biomass if the biomass cannot be separated. He asked what were the authors' experiences with biomass separation.

Weichers (South Africa) stated that the author referred to scale-up problems such as wall growth at laboratory scale was important. In South Africa, experience with anaerobic treatment of wine waste at laboratory, pilot and full scale showed that the load that can be applied can differ by two orders of magnitude as well as the types of settling rates obtained. He asked what scale should be used and what precautions should be observed. He added that settling cannot be scaled up or scaled down.

Pohland (U.S.A.) stated that it is unfortunate that the author (Andrews) of the inhibition model was not present. The model is not a comprehensive model and included only one acid-base equilibrium that can occur in an anaerobic system. Fortuitously, the organic acid contribution to the array of equilibria conditions is very important and often the reason why one can get correlations. However, one should not overlook other acid-base equilibria as well as complexation reactors that can affect the pH which, in turn, will affect the amount of ionized species present. It should be indicated to the authors and others that they should not use absolute values of concentration of unionized species since it is a function of the total species concentration as it relates to pH.

It has been indicated that inhibitors other than acids can affect efficiency. Since the model is based on acid-base equilibria, it does not account for other inhibitors. Sulfate studies bring into mind the inter-relationship between ORP and pH which has been discussed and researched in the past. One cannot uncouple acid-base pH from the EP. He concluded that inhibition modeling is a game played in curve fitting to explain data, and it tends to sophisticate our ignorance about what is really causing the inhibition.

Loewenthal (South Africa) stated that the authors noted that washout or sludge age is not included in the model while they state that wall growth which affects sludge age is an important factor in the results. If, in fact, the sludge age did affect the results, it would indicate the inhibition model does not have much meaning.

Kroiss (Austria) stated that they have run experiments for nearly one year on acetic acid wastes with high content of sulfur compounds. They have run pilot plants of 4-m^3 volume with wastes of high acid concentration up to 2000 mg/ℓ of total volatile acids. No failure was evident even up to 5 g/ℓ of volatile acid, but there was about a 33% drop in COD reduction (75-80% down to 50%). However, sulfate was reduced to sulfide with the most important figure being the ratio of COD reduction to sulfate in the influent due to the equilibrium between liquid and gas phases.

The author replied that he felt he could not really comment on the growth rate measurement. It was thought to be simply a measure of the volatile solids changes. He noted that the laboratory-scale reactor was 25-ℓ in volume, while the pilot scale was 6 m^3 and the full scale was 90 m^3. As pointed out, it is not really possible to scale-up, especially settling. The laboratory reactor was mentioned as a precautionary note. Experience with laboratory and pilot scale have shown similar indications. Full scale has not been run long enough for meaningful data. It appears that it is possible to obtain reasonably reliable data from pilot plants of 6-10 m^3.

It should be pointed out that the authors improved the inhibition model by including such parameters as carbon dioxide, bicarbonate and ammonia. The authors used the simplified version to see if it could reasonably explain the results and so far, perhaps fortuitously, it seems that results are in the range of the model. However, the cautionary suggestion is noted.

The sulfate effect has been handled in a different manner by the authors. The technique is to relate the sulfate to enzyme blockage which the speaker did not think is related to ORP.

On the subject of wall growth versus sludge recycle, the volatile acid effect was different on the two types of growth. The wall growth was less sensitive to the volatile acids and its influence on the results was not in proportion to the small amount of biomass but rather to its insensitivity to the external acetic acid.

The author's experience has suggested it is possible to operate at several thousands of mg/ℓ of acid and that operation at 5000 mg/ℓ is not a difficult point to reach.

D. Paper No. 55: "Process Integration in Sludge Management," by R. I. Dick, D. L. Simmons and Y. Hasit (U.S.A.)

The author stated that improvements in sludge treatment processing has resulted from the study of individual processes such as thickening, anaerobic digestion and dewatering without consideration of process interaction and integration. If process interaction, such as thickening reducing the anaerobic digester size, is considered as part of an optimally designed system, then the result will not include optimally designed individual component processes. The basis for optimal designed systems is to get the best out of each process in view of the overall scheme, not in view of the individual process.

The study procedure consisted of three major components, performance models, cost models, and an optimization procedure. The performance models were mathematical descriptions of the performance of wastewater and sludge treatment processes. The development of fundamental models was limited to the present state of knowledge. Since optimization using traditional rules of thumb is not possible, an attempt was to develop as fundamental a model as possible. In some cases, this was not feasible due to the current state-of-the-art and empirical models were developed. Such an example was sludge conditioning.

The second component was cost models developed from American practice. This is the weak point since accounting practices tend to be poor and there is difficulty in attributing costs to individual processes. It is also difficult to attribute costs on the basis of design and operational parameters. Much of the cost data was taken from an EPA report done by Metcalf and Eddy Inc. several years ago.

The third component was a computer optimization procedure with the objective of minimizing total annual cost. It was subject to constraints with some related to performance standards such as effluent requirements, heavy metals and nitrogen levels for land disposal and minimum anaerobic-digester detention time. The optimization procedure was developed by Ratner and Fox.

Some of the 29 quality parameters included nutrients and heavy metals in the soluble and particulate forms so as to be able to track them from process to process. Although fundamental models were used for thickening and dewatering equipment, empirical relationships were used between concentration and sludge settling velocity and between specific resistance and pressure differential.

The effect of the mean cell residence time for an integrated treatment system was illustrated. The system was primary treatment, activated sludge, combined sludge gravity thickening, anaerobic stabilization, chemical conditioning, vacuum dewatering, and trucking 32 km to agricultural land. The overall annual cost was lowered as the mean cell residence time was reduced.

Reduction of anaerobic digester and vacuum filtration size by increasing the sludge thickener size resulted in an overall reduced annual cost. The cost reduction of the digester was more than the increased cost of thickening. Significantly, the optimal thickener size was larger than conventional design practice.

It is important to note that thickening can have a significant effect on chemical properties, in addition to physical properties of sludge suspensions. The increase in thickener size resulted in a digested sludge higher in cadmium and nitrogen due to less dilution. Land application is controlled by plant available nitrogen so that less sludge will have to be applied and the cadmium level determined by the degree of thickening.

The effect of the transportation mode on the overall cost of a large 2.2 m^3/s plant showed ocean disposal was the cheapest for an anaerobic digested sludge. For agricultural land disposal, it appeared to be best not to dewater the sludge unless the distance was greater than 30 km.

The effect of the transportation mode on the overall cost for a smaller (0.44 m^3/s) plant showed that liquid sludge disposal by truck was the choice up to nearly 100 km. The expense of dewatering was not recovered in the transportation cost. Barging to sea was not particularly advantageous for a plant of this size.

For small plants, energy was not an important consideration in the total plant use. However, in larger plants energy did become a significant factor. In a previous paper, Wolf pointed out that aerobic thermophylic digestion was competitive at the smaller plant size which is in support with these figures.

As energy costs change, the method of integrating sludge processes will change. As energy costs increase, it would be prudent to use chemicals and thickeners to decrease energy-intensive vacuum filter size and increase digester size to maximize the gas yield, even though at present anaerobic digesters are allowed to go to minimum allowed sizes.

The present preliminary attempt of sludge management has shown that there are many instances of identifying what is not known. There are major gaps related to the physical properties of sludges. There is a lack of information on the effect of design and operation of sludge generation processes on the physical characteristics of the sludge produced. There is little information on the properties of a resulting mixture of two types of well-defined sludges. There is little information on sludge processes as relates to the physical properties such as from aerobic and anaerobic digesters.

The formal discusser, Kugel (Federal Republic of German), commented on the 30 parameters used to describe the processes and asked which ones have proved to be truly relevant. The approach used has been rational and has presented some positive comments on sludge thickening, sludge transport and land disposal of sludge. Of particular merit is the suggestion that the system must be looked at in its entirety. The optimization should include the end products: sludge, effluent and gas.

Capital costs can matter, yet the author assumed a constant 7% amortization rate. Has there been a variation in the 7% and, if so, has a sensitivity analysis been done? If there has been a range in the percent interest, what is the confidence level in the week? With reference to the periods in the economic analysis, the discusser stated that the present worth factor is dependent on the period of analysis and the interest rate used. With different interest rates or present worth factors, the breakeven point can be shifted. At this point, all investments with a high initial cost will be preferred while on the other side, it will be reversed.

The author replied that all of the 30 parameters were used with settling and dewaterability properties being used most frequently. Nitrogen was important in land application rates, although some indicate phosphorus is more important. Heavy metals were used in determining land application rates.

The 7% interest rate used was based on that recommended by the United States government at the time the paper was written, but the current rate is far above that value. A sensitivity analysis was done for interest rates up to 15%. Although it was found that costs were affected, there was no difference in the process interaction for the processes considered. The only period of amortization used was 20 years. It could be assumed that, based on interest rate changes, changes in the amortization period would change the total cost but not significantly change process interactions.

In floor discussion, Kroiss (Austria) asked if the process scheme of thickening, centrifugation and incineration had been modeled. He also asked if modeling of the long-term effect in thickening, including temperature effects versus sludge dewaterability, had been done.

The author answered that incineration had been found to be noncompetitive. Although at the time of the work the fuel cost was much lower, it appeared that incineration would be the choice only when there are other complicating factors, and not economics, were used. There has been no modeling on the long-term effect of thickening.

Jacobson (South Africa) asked for comments on where land disposal is not possible, should activated sludge residence time be as short as possible even if incineration is used?

The author replied that for incineration, the reduction in sludge volume accompanying long mean cell residence time is not worth the price nor is the improvement in physical properties worth the price.

Roberts (South Africa) asked that a figure showing the significance of energy costs as a fraction of plant size be plotted on a larger scale with some indication of the percentage of the plants that fall into various size categories. It appeared that the distinction of significant energy costs in small versus large plants was lost. There would be substantial savings to owners of small plants if they use energy necessary for certain processes rather than avoid using it.

The author answered that he will probably not replot the figure on a larger scale since it would indicate a degree of accuracy that does not exist. It should be emphasized that a larger percentage of the plants are small and are on the lower rising part of the curve where energy costs are not as important as is usually thought.

Von der Emde (Austria) asked the author if he considered the degree of treatment at the low sludge age values as well as the cost-benefit. The author replied that all solutions shown were subject to the effluent quality requirements of 30 mg/ℓ of BOD and 20 mg/ℓ of SS. The sludge age was not reduced below the point where the effluent quality requirement was not met. The very steep part of the curve at low mean cell residence time was due to the assumption that nitrification was not sustained at three days but was sustained at five days. The steep portion of the curve between three and five days was due to the increase in the oxygen requirement for the onset of nitrification. No ammonia or nitrogen removal standard was considered.

Jenkins (U.S.A.) stated that the paper seemed to advocate mixed thickening of primary and waste activated sludge. He asked if separate thickening would be better such as gravity thickening for primary sludge and dissolved air flotation for the waste activated sludge.

The author replied that very little information existed on the effect of mixing primary and secondary sludges. Calculations based on thickening characteristics of each do not yield the mixture characteristics. Some laboratory work was done to develop a model which indicated a nonlinear effect. This is the weak point in the model. Based on the model, it is ordinarily better to combine sludges when using gravity thickening. They did look at the effect of separate thickening before mixing. The recollection was that for very big plants it was a worthy scheme, and for small plants it was not.

Bahrs (Federal Republic of Germany) questioned the place of digestion in relation to incineration. If there is no digestion, there is a high organic mass to the incinerator. If there is digestion, gas is produced and there is a reduced organic mass to the incinerator. He questioned the author on the dewaterability change from digestion.

The author replied that it is prudent to question if digestion should precede incineration. Digested sludge will carry smaller amounts of mass and smaller amounts of water into the incinerator and thus improve the economics of incineration. He found that it was nearly a breakeven event. For large plants, it seemed better to digest first while for small plants, it was not. Based on the uncertainties, the author concluded he did not know the answer. There is great uncertainty on what the digestion does to dewaterability. From the preliminary laboratory results, it was indicated that there was a deterioration from digestion. In the model reported, it was assumed that there was no effect on dewaterability from digestion. This question remains an unknown.

IV. CRITIQUE OF SESSION

Paper No. 49 expressed combined costs consisting of running, energy and capital costs in comparing various sludge treatment processes. It was pointed out that energy costs have an increased significance when a national goal is energy independence. The question of pathogen kill in view of land disposal was not covered in sufficient detail for the ATS process. The effect of plant size, i.e., small versus large, on process selection was emphasized. However, it was pointed out that proper plant operation of such factors as power splitting, gas engines and energy planning could alter the process selection, i.e., by favoring anaerobic digestion to a higher degree. The paper appeared to be part of a continuing discussion on the use of anaerobic digestion or other competing processes based on plant size especially for smaller plants.

Paper No. 51 concerned data from a plant that received more potato waste than domestic waste, thereby narrowing the value of the paper. The process title was incorrect in meaning, but a correct title was suggested by a discusser. The process was pasteurization before digestion. The use of pasteurization was emphasized when considering land disposal. It was stressed that in the Federal Republic of Germany, pasteurization is to be required before agriculture land disposal although this process has been used as a rule in the past 15 years. Pathogen data were not available in this paper. Of special interest was the microbiological aspects of the digester and digested sludge put on the land. The place of digestion after pasteurization instead of before raised many questions, some of which were not answered.

The formal discusser of Paper No. 53 stated that the information in the paper should be brought out more clearly. He challenged the authors use of a parameter in the inhibition equations. The use of the particular inhibition equation used was criticized for its simplicity and avoidance of other active components. The effect of scale-up of laboratory, pilot and full-size plants was brought up in the floor discussion.

Paper No. 55 acted as an integrator of the three previous papers on individual unit processes by emphasizing the concept of an overall sludge management system. The paper concentrated on one flow scheme which restricted the scope of the paper although this was expanded during the floor discussion. Many examples of areas where lack of knowledge exists were given. The question of plant-size effect on process selection was discussed in view of the present paper as well as that of Paper No. 49, which reinforced each other. The smaller relative importance of energy in smaller plants was stressed strongly.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The use of aerobic thermophylic digestion (ATS) is especially suited to smaller plants and was found in this case to be superior to aerobic digestion and anaerobic digestion. The process does require a high volatile solids content. The process might be valuable in the smaller plants in the United States. Increasing the degree of stability of the ATS sludge is an area that needs further research.

The use of sludge pasteurization is not practiced in the United States. However, as land disposal of sludges increases, this approach to eliminate the pathogen hazard certainly has merit in comparison to other methods. The apparent success reported for pasteurization before digestion would suggest a significant study of the microbiological aspects involved.

The subject of inhibition in anaerobic sludge digestion is, has been and will be of great interest in the United States. These results are certainly applicable to United State water pollution problems. The impact of propionic acid and hydrogen as an important intermediary are major research needs.

The subject of process integration in sludge management is now being studied with reference to United States water pollution problems. The research needs concern areas such as the physical changes resulting from mixing different kinds of sludges, costs data on the proper basis, and the effect of design and operation on the resulting sludge characteristics.

I. SESSION

A. Day: Friday, April 2, 1982
Hall: B
Time: 2:00 to 5:35 p.m.

B. Theme of Session: Biological Nitrification and Denitrification

II. REVIEWER

A. Name: Paul L. Bishop

B. Position and Affiliation: Professor of Civil Engineering
University of New Hampshire
Durham, NH

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 57: "Elements of the Inhibition of Nitrifying Bacteria," by G. Martin and Y. Richard (France)

This paper examined the inhibitory influence of mineral and organic pollutants on the biokinetics of ammonia oxidation to nitrates by a mixed culture of nitrifying bacteria. The purpose of the study was to determine the concentration at which various heavy cations, phenol and trichlorophenol become inhibitory to nitrifying bacteria. These studies were carried out using laboratory-scale batch and continuous-flow activated sludge units and using a glass column filled with activated carbon or biolite to simulate a fixed film submerged filter. Inhibitory concentrations were determined by measuring the nitrification rate and the growth rate for various concentrations of the selected toxic material.

The inhibitory effects of nickel, cadmium, copper and zinc were investigated. The authors reported that in no case was toxicity observed when the cation concentration in the wastewater was below 1 mg/ℓ. The authors further stated that the maximum rates of inhibition observed for the concentrations of cations evaluated varied from 25 to 88%. Inhibition was reported to be due to adsorption of the metallic ions on the flocs containing the nitrifying bacteria and resultant blocking of enzyme mechanisms.

In order to determine the actual state of the cations added to the feedwater (free or precipitated with phosphates, carbonates, OH^- and NH_4^+), the authors conducted a side study to measure the amount of free cation in solution after addition to a buffered water containing $CaCO_3$. The results indicated that very little of the cation added remained in solution; generally, there was less than 1 mg/ℓ.

Bacteria present in the fixed-film system were found to generally be less sensitive to inhibition by heavy metals than the free bacteria in the activated sludge systems. Little or no nitrification inhibition was observed in the activated carbon filter column at metal concentrations as high as 22.5 mg/ℓ.

Investigations of the effects of phenol and trichlorophenol on nitrification were performed using batch reactors. The addition of phenol caused a cessation of nitrification for a period of time, after which nitrification resumed, but at a reduced rate. At the end of the aeration period, the phenol remained undegraded. The authors stated that this was due to a gradual adaptation of the bacteria to the presence of the phenol. With trichlorophenol, there was an increasing inhibition of nitrification as the concentration increased, similar to that found for heavy metals evaluated. The amount of toxicity reported was substantial, reaching 98% at a trichlorophenol concentration of 12.5 mg/g VSS.

The inhibitory effects of organic compounds in submerged filters depended upon the adsorptive properties of the filter media. With activated carbon as the support medium, no inhibition by phenol was observed because the phenol was completely adsorbed by the activated carbon. With biolite, a clay material which absorbs little phenol, there was complete inhibition of nitrification. The support media in a fixed film reactor may therefore be chosen to help mitigate the inhibitory effects of a toxic organic compound.

The invited discusser, Jenkins (U.S.A.), questioned the validity of the results presented because the toxicity thresholds presented were based on total cation concentrations added to the feedwater, rather than the amount of metal actually in solution, even though the authors demonstrated that the total metals in solution were several orders of magnitude less than that added. Jenkins further stated that the authors ignored formation of metal ion complexes with constituents of the feedwater (hydroxides, carbonates and aqueous ammonia). He presented log-concentration versus pH diagrams for the metal-ligand systems used which showed that for the pH range used in the experiments, the major soluble metal species for nickel, cadmium and zinc were the hydrated cations, while for copper the major soluble species was the aqueous copper carbonate complex, followed by the copper ammonium complex, and then finally by the cupric ion. Since the toxicity of metals varies widely with speciation (for example, copper carbonate is virtually non-toxic to fish while copper ions are highly toxic), it is essential to know what metal species are present when performing toxicity studies.

Jenkins (U.S.A.) stated that lack of consideration of metal precipitation caused the authors to misinterpret their toxicity data. The authors reported that inhibition of nitrifers increased with increasing metal concentration and then fell off to a constant value. They proposed that this was due to a toxicity threshold for the metals. Jenkins (U.S.A.) felt that this finding could be explained by the fact that as one adds more and more metal, one reaches the solubility threshold of that metal, after which the concentration of metal ion in solution remains constant resulting in a constant degree of toxicity. He concluded that there would be great difficulty in applying the authors' data on metal toxicity to nitrifers in any general fashion or to waters other than those used by the authors.

Martin (France) agreed with Jenkins (U.S.A.) that solubility calculations indicated that a high degree of precipitation can occur in the feedwater, but he felt that pK calculations were not very accurate with activated sludge because of its complexity.

Neufeld (U.S.A.) suggested that it would be better to measure the metals actually on the sludge flocs as opposed to using the concentration in the bulk liquid, since toxicity will be caused only by the metals in contact with the nitrifers. Martin agreed but stated that it is much easier to measure the soluble metal concentration than to measure either metal concentration on the floc or speciation in the liquid.

Matthews (United Kingdom) asked whether the authors had attempted to distinguish between production rates of nitrite and nitrate. Since there are two distinct organisms involved and *Nitrosomonas* species are generally much more sensitive than *Nitrobacter* species, the inhibitory effects should be different. However, Martin responded that they did not detect the presence of nitrite in their samples, indicating that the inhibition was on *Nitrosomonas* species.

B. Paper No. 59: "Biological Nitrification in an Up-Flow Fixed Bed Reactor (UFFBR)," by G. M. Faup, A. Leprince and M. Pannier (France)

The authors proposed a kinetic model to represent ammonification and nitrification occurring in upflow-fixed bed reactors (UFBR) receiving direct air injection into the support medium. Fixed bed reactors were investigated rather than the activated sludge process because an UFBR contained greater concentrations of active nitrifying organisms and, consequently, could be considerably smaller than comparable activated sludge reactors.

A pilot-scale UFBR receiving effluent from an activated sludge reactor was used in this research. Analysis of the average ammonia profiles in the reactor indicated that at filtration rate of 5, 7.5 and 10 m/h, the ammonia nitrogen concentration decreased linearly with height in the reactor. This linearity indicated that ammonia was not limiting and that the ammonia oxidation rates was at its maximum over the whole height of the reactor. The concentration of active nitrifying biomass was determined based on the ammonia removal rate in the reactor, the reactor retention time, and the Monod equation. The biomass concentration was found to be primarily dependent on filtration rate and filling material characteristics, and to be independent of height within the reactor. When the filtration rate was reduced to 3m/h, the ammonia profile was no longer linear but instead was exponential, indicating that the ammonia was limiting. In addition, active nitrifying biomass concentrations varied with height.

Comparison of the UFBR system with a pilot-scale nitrifying activated sludge system showed that it was possible to reach active biomass concentrations eight to nine times higher in the UFBR than in the activated sludge system.

The authors also modeled the transformation of organic nitrogen into ammonia nitrogen and compared their model with results from their pilot-scale UFBR. The computed and measured soluble organic nitrogen profiles correlated very closely. Organic nitrogen removal was far from complete before the wastewater exited the reactor, thus limiting the overall conversion of nitrogen compounds to nitrate.

Additional findings included the observation that increasing the air/water ratio resulted in increased nitrification, attributed to the greater turbulence, and that substantial reductions in soluble COD and suspended solids also occurred.

Neufeld (U.S.A.), the assigned discusser, stated that the authors presented valuable field data which confirmed intuition concerning biofilm nitrification kinetics, but that the model presented was oversimplified. In particular, the model was based on applying kinetic data taken from activated sludge nitrification systems to the UFBR system. Neufeld (U.S.A.) indicated this would result in an underestimation of biokinetic constants because the Reynolds Number and μ_{max} values should be higher in the UFBR system. He suggested the development of a predictive model based on fundamental parameters, such as diffusional effects, biofilm thickness and specific surface area of the support media. He questioned the use of the nitrifying biomass concentration as presented, since substrate removal was not a function of total biomass, but rather a function of the biofilm exposed to the bulk flow. Thus, film diffusion as influenced by turbulence becomes a critical design parameter, as was alluded to by the authors when they found that increasing the air/water ratio increased the degree of nitrification.

Leprince (France) responded that he would like to use a more extensive model, but their purpose was to find a simple model to compare the effects of various hydraulic rates for use at the industrial development stage. The simple model presented was easier to use to quickly select a filtration rate which can be used at full scale.

Harremoes (Denmark) questioned the statement that ammonia was not the limiting factor. He stated that it is necessary to distinguish between stoichiometric limitation and rate limitation. He also disagreed with the interpretation by the authors and Neufield (U.S.A.) concerning the role of increased air/water ratio on increased nitrification. Harremoes (Denmark) stated that recent biofilm kinetic research shows that oxygen is usually the rate-limiting substrate in nitrification and that the increased rate of nitrification resulting from increasing the air/water ratio was due to increased oxygen concentration in the biofilm. Using oxygen transfer calculations, the oxygen profile through the reactor could be determined. Applying this to the model would make it a better predictive tool.

Leprince (France) responded that he could not state whether oxygen was the limiting substrate or whether the increased Reynolds Number was the main factor, but he stated that the oxygen concentration in the reactor never dropped below 4 mg/ℓ. Neufeld (U.S.A.) agreed that the oxygen concentration was high enough to prevent oxygen limitation and that the reason for increased nitrification was the increased turbulence achieved. Holden (Australia) reported that the question of whether oxygen was limiting in biofilms could be determined by examining the diffusion coefficients and concentrations of the substrate and oxygen at the biofilm surface. Dansk (Federal Republic of Germany) stated that the role of increased air/water ratios could be resolved with further studies using different gas mixtures of nitrogen and oxygen.

C. Paper No. 61: "Simulation of Nitrification and Its Dynamics in a Rotating Biological Contactor," by Y. Watanabe, H. E. Bravo and K. Nishidome (Thailand, Japan)

The authors proposed a pseudo-steady-state model of nitrification in partially submerged rotating biological contactor systems. Steady-state substrate concentration profiles within the biofilm cannot be assumed because the ammonia flux to the biofilm is a function of its spatial position as it rotates alternately in the air and liquid phases, but the authors stated that the fully submerged steady-state model proposed adequately models overall results in terms of the average ammonia flux to the bioflim.

The steady-state model was based upon molecular diffusion with a simultaneous zero-order nitrification reaction within the aerobic or active biofilm. At steady-state, the transfer rate of the substrate into the biofilm was equal to its flux at the biofilm surface. The proposed theory stated that the rate of nitrification per unit biofilm surface area may be expressed as the product of an overall rate constant and a steady-state bulk ammonia concentration. The overall rate constant consisted of two coefficients, one of which described the transport of ammonia to the biofilm surface and the other described the diffusion process with a simultaneous zero-order nitrification reaction within the active biofilm.

A computer simulation of nitrification in a partially submerged RBC was developed and operated under varying conditions. Comparison of the simulation results with experimental results from the steady-state model showed that the nitrification rate predicted by the model could be almost equal to the average nitrification rate of each element of biofilm indicating that the steady-state model could be used for a partially submerged RBC. However, the zero-order nitrification reaction was found to hold true only for ammonia concentrations in excess of 3.0 mg/ℓ.

The authors also used the model to study the nitrification process in the dynamic state. Varying ammonia concentrations were imposed on the simulation study using a pulsed format. It was observed that during changing bulk substrate concentrations, at first there was some transient rise of the mass flux at the biofilm surface, but only for a relatively short time interval, followed by a new steady-state mass flux. Because the transient period was found to be very short, the authors assumed that pseudo-steady-state conditions could be used when the system is in the dynamic state.

The model was verified experimentally using a laboratory-scale RBC unit operating under pulsed load conditions. The experimental data fit very closely to the data derived from the dynamic model. The rate of ammonia oxidation in the biofilm was constant for the entire length of the experiment, indicating that the nitrifiers were working at maximum efficiency at all times, independent of the residual ammonia concentration. This verified the assumption of a pseudo-steady-state in the biofilm.

The authors stated that very high ammonia concentrations during transient periods resulted in substrate and product inhibition caused by free ammonia, but that the inhibition was not permanent and could be removed.

The invited discussion was prepared by Saunders (U.S.A.) and presented by Chian (U.S.A.). He emphasized that the model presented is only applicable to wastewaters high in ammonia nitrogen and devoid of organic matter. The model accounted for neither BOD removal nor denitrification.

Saunders (U.S.A.) disagreed with two assumptions used in developing the dynamic model. Rather than assuming that nitrifying bacteria exhibit a very small lag in growth rate when exposed to sudden changes in ammonia concentrations, as proposed by the authors, he suggested that it would be more appropriate to assume that substrate uptake by dormant organisms would occur without a significant lag. He also disagreed with their assumption that ammonia concentrations up to 60 mg/ℓ would not inhibit nitrification. He stated that inhibition by ammonia was a function of pH, that free ammonia was the inhibiting form, and that ammonia concentrations as low as 0.1 to 1.0 mg/ℓ are inhibitory to *Nitrobacter*. At the pH and ammonia nitrogen concentration conditions used in these studies, bulk-phase free-ammonia concentrations would have varied from 0.5 to 1.9 mg/ℓ , which would have inhibited *Nitrobacter* but not *Nitrosomonas*. This would have resulted in high effluent nitrite and low effluent nitrate concentrations, as was found in all cases by the authors. Saunders (U.S.A.) concluded that inhibition by free ammonia occurred throughout all of the steady-state and dynamic tests, thus greatly limiting model verification.

Watanabe (Japan) replied in these studies, *Nitrosomonas* were not inhibited even by relatively high levels of free ammonia. However, he did agree with Saunders (U.S.A.) concerning inhibition of nitrate oxidation by free ammonia. He further stated that nitrification occurred within a very small thickness of the biofilm and that the concentration of ammonia in the biofilm is considerably different than that in the bulk liquid.

Dick (U.S.A.) noted that heterotrophic activity was ignored and questioned what the effect of cell lysis products would be. Watanabe (Japan) responded that an organic-carbon-free synthetic wastewater was used in order to develop a simple model. The effect of these organics from cell lysis on the system was unknown.

D. Paper No. 63: "Effect of Denitrification on the pH in Biofilms," by E. Arvin and G. Kristensen (Denmark)

This research, concerned with the effects of biological denitrification on pH in fixed biofilms, showed that the pH in the interior of the biofilm can be considerably higher than the pH in the bulk liquid. This is believed to be due to resistance to diffusion of bicarbonate and carbonate produced from the oxidation of a carbon source. The paper presented a model for the pH profiles in denitrifying biofilms and the experimental verification of that model.

Calculations for the pH profile involved mass balances for nitrate, total inorganic carbon and alkalinity, together with ion equilibrium equations for the inorganic carbon components and the water. To avoid the use of complicated numerical methods, a simplified two-step analytical procedure was used which, unfortunately, resulted in a pH profile which was discontinuous. The discontinuity occurred at the point in the active biofilm where the concentrations of carbon dioxide and carbonate become equal (i.e., at the depth where pH = 8.4).

A laboratory-scale, rotating-drum, fixed-film reactor was used to experimentally verify the model. Measurements for pH could be made in the bulk liquid and at the biofilm/support medium interface by use of an electrode built into the reactor wall. It was assumed that the pH at the wall was the same as that at the bottom of the active zone of the biofilm. All experiments were performed with the pH of the bulk liquid less than 8.4; feed-water nitrate concentrations were varied to vary the active biofilm thickness. Results from these experimental studies match very closely those predicted by the proposed theoretical pH model.

The diffisional coefficients for nitrate, carbon dioxide and bicarbonate in the biofilm were found to be roughly 50% of the values in pure water. Reaction rate values were presented. The pH effect was influenced significantly by the alkalinity in the bulk liquid. Larger pH increases resulted when the alkalinity in the bulk liquid was low.

The authors discussed the possible effect of the Donnan potential created by the ion concentration distribution at the biofilm/bulk liquid interface. This should have the effect of increasing the concentrations of all cations, including H^+, in the biofilm compared to the bulk liquid, thus depressing the pH at the biofilm surface. However, attempts to measure the Donnan factor in the experimental studies were inconclusive.

Discussion of this paper was begun by Cornier (France). He stated that the authors had provided a good theoretical explanation for biofilm pH increase due to diffusion resistance in the biofilm. However, he felt that diffusion through the bulk liquid/biofilm interface could also be significant and questioned whether a lack of turbulence at the interface could be controlling diffusion. The author responded that all experiments were done at 100 rpm and that previous studies had shown that there was no influence on reaction rates when the rotational speed was increased above 30 rpm. Therefore, the reaction rates were completely controlled by diffusion and reactions within the biofilm and were independent of liquid film diffusion.

Cornier (France) asked whether the methanol added as a carbon source would have an effect on membrane expansion. Arvin (Denmark) replied that he did not think the methanol would have any effect because of the low concentration present.

Arvin (Denmark) remarked that pH changes in the biofilm were important because they could play a role in such things as the precipitation of calcium phosphate inside denitrifying biofilms. Roberts (South Africa) reported, however, that he had never found calcium phosphate needle crystals in denitrifying activated sludge.

Jones (Canada) questioned whether the results presented here for denitrifying biofilms could be extrapolated to include pH changes in free floc. The author responded that he had done no work with flocs, but he expected that the results would be similar to a biofilm. Nozaik (South Africa) asked whether the pH effect would go deeper into the biofilm if the biofilm was thicker. The author replied that this would depend on whether volatile acids were produced since the deeper zones would be anaerobic. If methanol was the primary carbon source, there would be no large production of volatile acids to depress the pH and the pH effect would not be affected. This may not be true for other organic carbon sources, however.

IV. CRITIQUE OF SESSION

The session consisted of three papers dealing with biological nitrification and one concerned with denitrification. All four papers generated considerable debate, particularly concerning experimental design procedures and data analysis.

Paper No. 57 investigated the inhibitory influence of nickel, cadmium, copper, zinc, phenol and trichlorophenol on nitrifying bacteria. Inhibitory concentrations were presented for each of these materials. Unfortunately, however, the toxicity thresholds presented for the heavy metals were based on total cations concentrations added, rather than on the amount actually in solution. Because of metal precipitation and complexation reactions, the thresholds observed may have been due to solubility limitations rather than to toxicity limitations.

Paper No. 59 presented useful pilot-scale results from an up-flow fixed bed biological nitrification reactor and a simple mathematical model for the system. These data could be very useful for future designs. Most of the debate was concerned with the authors' interpretation than an increased air/water ratio in the reactor resulted in increased nitrification because of the greater turbulence generated.

Paper No. 61 presented a pseudo-steady-state model of nitrification in a partially submerged rotating biological contactor. This was an extension of work previously published on fully submerged RBCs. The model correlated well with results from laboratory studies.

Paper No. 63 provided a very interesting experimental proof that the pH in a denitrifying biofilm varies with depth due to a buildup of bicarbonate and carbonate in the film. A model for the pH profile in a denitrifying biofilm was also presented.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The papers in this session all dealt with biological nitrification and denitrification, subjects which are being researched intensively in the United States. Since all of these papers were presented by researchers from Europe and Asia, as was most of the discussion, they should be of great interest to American researchers and engineers.

All four papers were concerned with fixed-film reactors, whether for nitrification or denitrification. This is an area where European researchers have much more experience than their American counterparts because RBCs and upflow filters have been in use in Europe for much longer than in the United States. The paper on nitrification in up-flow fixed bed reactors is particularly timely as several research projects of a related nature are now on-going in the United States. The kinetic and dynamic models presented, while possible oversimplified, provide relatively simple techniques for predicting the performance of biological nitrification systems.

I. SESSION

A. Day: Monday, March 29, 1982
Hall: C
Time: 11:45 a.m. to 5:35 p.m.

B. Theme of Session: Wastewater Impacts and Uses for Water Supplies

II. REVIEWER

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III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 3: "Development of Water Reclamation Technology in South Africa," by A. J. Clayton, L. R. J. van Vuuren and B. Roux (South Africa)

This paper reviewed major results of the operation of the Stander wastewater reclamation plant (SRP), a research-demonstration facility in Pretoria, South Africa, and operational modifications which were incorporated into the wastewater reclamation (WRP) in Windhoek, Namibia during 1976 and 1979. It also evaluated various aspects of the development and operation of the Windhoek plant.

Over the ten-year period from 1970 to 1980, several modifications of the SRP were instituted in response to such problems as difficulty in the optimal control of breakpoint chlorination due to diurnal and seasonal variations in ammonia concentrations, and optimization of the economics of activated carbon absorption for the removal of organics. High lime treatment (HLT) and ammonia stripping (AS) were introduced at the SRP to deal with the widely fluctuating ammonia levels in the biofilter humus tank effluent. An equalization basin was also incorporated. The activated carbon resin bed capacity was doubled because the fluctuating humus tank effluent required uneconomically high quantities of powdered activated carbon. When activated sludge effluent became available at the SRP in 1975, it was shown that chemical coagulation could substitute effectively for HLT, and AS was no longer required.

Direct reuse of reclaimed wastewater for a public water supply was implemented at Windhoek using the WRP I in October 1968.

Early in 1971, as a result of increased loading, poor quality of the maturation pond effluent led to the discontinuation of the operation of the reclamation system. In 1972 the latter was modified to incorporate HLS and AS and operated as WRP II. In the period 1972 to 1979 production was frequently interrupted due to rapid scaling in the ammonia stripping tower and problems with other equipment. Effluent from a new activated sludge treatment system became available in 1979 and was used along with alum flocculation instead of HLT and AS in WRP III. During the subsequent twelve-month period, there were 25 weeks of operating time during which 5 x 10^5 m^3 of reclaimed water were produced, constituting about 16% of the potable water supplied to the population of one zone of the city.

It was stated that operation of the WRP III "presents no difficulty and is far simpler than that of the former treatment modes." There were higher increases in sulfate, chloride, total dissolved solids, and total hardness in the final effluent than in the WRP II, but these were judged to be acceptable. Levels of microbiota, pathogenic or otherwise, were also considered acceptable in all modes of reclamation.

The WRP III was more economical than previous modes. Nevertheless, it is more expensive than existing supplies, but cheaper than the cost of developing additional sources. Activated carbon is its highest cost. Therefore, it is important that the biological treatment process be operated efficiently to minimize the load on activated carbon. It was concluded that the Windhoek plant has proved the practical feasibility and absolute safety of direct reclamation.

Heaton (U.S.A.), the invited discusser, noted his agreement that it is more important to know the quality of water than its history. In response to his question about public involvement in reuse decisions. Clayton (South Africa) indicated that there was no great negative reaction, and there has been some public concern about insufficient utilization of treated wastewaters. Heaton (U.S.A.) asked about future developments, and van Vuuren (South Africa) indicated several were under study or development, including use of ozone in conjunction with activated carbon, and the integration of wastewater treatment and reclamation. The latter would include first the removal of solids and coagulatables, then biological treatment, and finally physico-chemical processes. It was emphasized that at Windhoek there is a fairly effective separation of domestic and industrial wastes, and this is an important factor in the selection of a system to supply potable water.

In response to a question about the maximum fraction of renovated water mixed with conventional sources that might be used, Clayton (South Africa) indicated that there is no reason why it could not be 100 percent. He noted that at Windhoek in WRP III, for one month one area was receiving about 70% reclaimed water with an average of 34% for one year.

Wachs (Israel) indicated that in Israel, prior to reuse, renovated wastewater is stored in aquifers following intensive treatment. The advantages are that the storage phase helps public acceptance and also provides an important time period for monitoring to detect any potentially harmful constituents. In response Clayton (South Africa) noted that a fish biomonitoring system is being installed at Windhoek to assist in the early detection of toxicants.

B. Paper No. 6: "Removal of Potential Carcinogens and Toxicants by Treatment Systems for Direct and Indirect Reuse of Wastewater Evaluated by Means of a Hamster Cell Culture Assay," by R. Kfir and O. W. Prozesky (South Africa)

This study used a mammalian cell transformation assay to test for potential carcinogens and toxicants in wastewater reclaimed for potable purposes, as well as in wastewater samples at various stages prior to the finished water. It compared direct and indirect reuse systems studied in April through July 1980. The direct reuse system was that a Windhoek in Namibia, described previously by Clayton et al. and referred to there as WRP III. The indirect reuse system used water from the Rietvlei Dam which has been an auxiliary source of potable water for the city of Pretoria, South Africa, since 1933. The Hennops River, which flows into the reservoir, receives secondary sewage effluent from an industrial community with two treatment plants 15- and 25-km upstream from the dam. A very high proportion of the flow to the reservoir consisted of effluent from these plants.

The water samples were analyzed directly following filtration through a 0.22 μm membrane filter. Hamster cells were used in the transformation assays when the cultures were three to six days old. Using a media made with the water test sample, and following an eight-day incubation, percent transformation and percent survival was determined by counting colonies, with benzo-a-pyrene as a positive control.

Both the direct and indirect reuse systems were found to reduce the toxic and transforming activity of the water to low levels. In both systems the percent transformation of the finished water was lower on each test date than samples at earlier stages of treatment or, in the case of the indirect system, than upstream samples. However, data were not presented for the finished direct system water from WRP III, but only after it was mixed with conventionally treated water. For the direct system, the percent survival for the finished water was sometimes lower than at previous stages of treatment, and even lower than that of the benzo-a-pyrene positive controls. For the indirect system the percent survival for the finished water was the highest on each sampling day although sometime marginally so. No clear correlation was found between chlorine levels and toxic or transforming activity for both reclaimed waters.

It was concluded that for water samples in which there was no correlation between levels of toxicity and transformation, these two activities were probably due to different substances in the water. It was judged that the finished water from the indirect reuse system was of slightly better quality than that of the direct one. Referring to another study, it was noted that fewer potential carcinogens and toxicants were present in both systems than were found previously in a good quality drinking water.

The invited discusser, Andelman (U.S.A.), noted that the approach of comparing the toxicity of various waters was useful and asked what evaluative role this test system could play in conjunction with others. Prozesky stated that a battery of living organisms should be used to evaluate potential human health effects, but that such analyses are expensive and complex and, therefore, should best be used to assess a reuse system and its optimal operation, rather than for frequent testing of individual samples. In response to questions by Andelman on the inherent variability of the method, and also why they did not concentrate their samples, Prozesky replied that they did not have the opportunity yet to measure reproducibility; also that they did not concentrate the samples so as not to increase cell toxicity to undesirable levels, and also to avoid the problems of introducing artifacts and selecting for some constituents at the expense of others.

Best (South Africa) called attention to statements that in the direct reuse system, the carbon filter often did not reduce and even increased toxicity and transforming capacity and asked if that might indicate that the carbon filter was adding or producing toxicants under some conditions. The author replied that at least on one day when this occurred, the carbon columns were overloaded, were being adjusted, and the product water was not being used.

Englande (U.S.A.) commented that his studies were also using a mammalian cell culture test system and that they were concentrating by a factor of one-thousand by lyophilization; also they were compositing samples throughout the day to minimize peak responses. Van Rensburg (South Africa) noted that renovation system studies involving spiking with known organic chemicals indicated that a large number of these compounds were broken down by chlorination. It was indicated that this could influence the mammalian system test results which showed that following chlorination and sand filtration, the level of toxicants and potential carcinogens in the finished water was usually reduced in the direct reuse system.

C. Paper No. 9: "Organic Micropollution of Potable Water Supplies: Indirect versus Direct Reuse," by J. F. J. van Rensburg, S. J. Theron, A. J. Hassett and P. G. van Rossum (South Africa)

Organic chemical and other water quality parameters in indirect and direct wastewater reclamation systems used for public water supplies in South Africa and Namibia were compared. The systems were the same ones described by Kfir and Prozesky (Paper No. 6). The Windhoek direct-reuse system was sampled for a period between two activated carbon cycles, while the indirect Rietvlei Dam system sampling period was from late summer through early fall.

The organic chemical constituents studied included six categories or groups of chemicals: volatile halogenated hydrocarbons (VHH), i.e., trihalomethanes; chlorinated hydrocarbons and pesticides (CHP); chlorophenols (CPHEN); polynuclear aromatic hydrocarbons (PAH); phenolic compounds (PHEN); and other compounds (DIV), such as dibutylphthalate and nitrotoluene. Lower hazard limits, either 0.1 or 1.0 μg/ℓ, were specified for each compound, as were organic pollution indices developed for various groupings of these compounds according to their frequency found in various concentration ranges. Other organic parameters measured were total organic carbon (TOC), trihalomethane content of samples exposed to chlorine, and UV absorbance at 275 nm. Fecal coliforms and two steroids were measured as indicators of fecal contamination, and Ames *Salmonella* tests were used to assess mutagenicity.

Based on a comparison of these various measured constituents, finished chlorinated water of the direct-reuse Windhoek system was judged to be of very high quality and better than that of the indirect reuse system. The organic constituents in the Windhoek system, such as VHH and TOC were not eliminated by the conventional water treatment processes, but were considerably reduced following activated carbon filtration. In comparison, finished indirect-reuse water contained substantially greater quantities of organic constituents. Also, some mutagenicity was detected in the latter effluent, but not in that from an experimental direct renovation system (i.e., the Stander plant). Mutagenicity was not measured at the Windhoek plant.

It was concluded that the direct reuse system was preferable to the indirect system because of its "multiple barriers" against chemical pollutants and pathogenic organisms. It was noted that a previous study had demonstrated that a direct water reclamation system could cope with high loads of toxic chemicals.

DeWalle (U.S.A.), the invited discusser, emphasized that the measurements indicated that the principal difference in quality between the finished effluents of the direct and indirect reclamation systems could be attributed to the use of activated carbon in the former; and that, if it were used in the indirect system, the two waters might very well be of equivalent quality. Van Rensburg (South Africa) agreed and recommended that whenever indirect reuse was practiced, serious attention should be directed to the possible need to improve organic chemical quality by use of activated carbon or other treatment processes.

Andelman (U.S.A.) and Shuval (Israel) raised questions concerning the concentration levels found or the hazard limits specified by the authors for trihalomethanes and other organics. The author indicated that these limits were essentially targets or warning levels, not precise health-related action levels. Shuval (Israel) emphasized that when such compounds known to be mutagenic are present, or mutagenicity tests are positive, as was found in the indirect reuse finished water, sound water treatment technology should be used to remove them. The author replied that some caution should be exercised in the use and interpretation of such tests in that increased sensitivities associated with high concentration factors are likely to result in many waters being positive, and thereby judged to be unsafe, when in fact their actual risk to human health may be difficult to assess.

D. Paper No. 12: "The Economic Impact of an Urban and Industrial Complex of Mineral Pollution in the Water Supply--a Case Study," by J. J. C. Heynike and S. F. McCulloch (South Africa)

This case study was a cost estimate of the impacts of projected mineralization of a storage basin (the lower "Barrage") along a stretch of the Vaal River in a large (17,000 m^2) area surrounding Johannesburg, South Africa. This area has a population of about 5 million and the mineralization is from gold mining and urban-industrial development. Presently, about two-thirds of the water supplied to the area is from the Barrage basin, and one-third is from the upstream Vaal Dam impoundment.

The present mineralization is mainly due to continuous dewatering of gold mines, the dissolution of salts from mine rock and sand dumps, and sewage and industrial wastes. The two largest sources of dissolved solids were mine pumpage (25%) and municipal sewage (14%). In 1979, the average total dissolved solids (TDS) in the Barage was 660 mg/ℓ. It was projected that without action this could rise to an average of 1000 mg/ℓ by 1990, with peaks of 1500 mg/ℓ. The present annual average TDS in consumed water (presumably from all sources) is 300 mg/ℓ. It was estimated that without further action this could rise to 500 to 800 mg/ℓ. Projection of increased costs to the consumer as a result of or to compensate for the increased mineralization was based on these two values of TDS.

Examples of the types of costs that were considered were: (a) household: impact on plumbing and increased use of soap and detergent; (b) industry: treatment costs; and (c) water supply authority: increased treatment costs and expansion of reservoir capacity. Based on present charges to bulk water consumers, it was estimated that the costs due to increase mineralization would be an additional 100 to 150%.

Several courses of action were suggested to prevent the increased mineralization. There were: (a) prevention of mineralized effluents from entering the Barrage; (b) improvement of water management techniques; (c) desalination and reuse of effluents, and their disposal by evaporation or otherwise; and (d) augmentation of raw water with other sources, although this was considerd only a temporary measure.

Herold (South Africa), the invited discusser, noted that the economic impact from TDS is an important new analysis in that it emphasized non-public health effects of community water supplies. He and the speaker indicated that additional costs were not considered that could be important, such as the increased sewer and sewage treatment costs, and the possible impact on downstream agricultural users of the water. Another discusser pointed out that a useful control strategy might be the collection of high TDS effluents and their selective treatment. It was emphasized that the main purpose of this study was to quantity costs associated with increased mineralization so that it would aid in decision-making on a variety of water supply projects under consideration.

E. Paper No. 15: "Limnological Effects of the Elimination of Phosphorus from the Wahnbach Reservoir," by H. Bernhardt and J. Clasen (Federal Republic of Germany)

This study evaluated limnological effects of the Wahnback Reservoir over a three-year period (1978-1980) following substantial reduction in phosphorus in the principal source of influent water, i.e., the Wahnbach River. The reduction was achieved by treatment of the river prior to its flow into the reservoir. The phosphorus elimination plant (PEP) utilized precipitation, flocculation and filtration to reduce the total phosphorus content (P_{tot}) of the effluent to 5 μg/ℓ, from an initial concentration of 100 to 150 μg/ℓ.

The reservoir containing 4 x 10^7 m^3 of water was used for the drinking water supply of the city of Bonn and surrounding communities. Beginning in 1957, eutrophication increased to the point that large quantities of algae broke through the water treatment filter, requiring additional flocculation. The growth of diatoms and other algae caused shorter filter time runs and a considerable decrease in treatment plant throughput. Other associated problems included bad taste and odors, as well as inhibition of the coagulation process by organic chemicals from the algae.

Phosphorus compounds came from scattered communities and farms as well as from erosion of agricultural areas. It was decided that it would be more cost-effective to treat the river effluent than to divert and treat the inputs to the river. Following the institution of treatment, the reduction of phosphorus in the river effluent began to affect the reservoir starting in 1978. To judge the impact on the reservoir, P_{tot} criteria concentrations were established to relate to its limnological state. These were that there was an 80% probability that the reservoir would be oligotrophic if the P_{tot} was less than 8 μg/ℓ (volume-weighted, annual average). The similar tolerable mesotrophic dose was 25 μg/ℓ. Based on these criteria, it was judged that the reservoir in 1979-80 was in a transitional phase between oligotrophic and mesotrophic.

The phosphorus reduction in the river effluent to the reservoir was about 90 percent. The average annual concentration of P_{tot} in the reservoir itself were reduced considerably from 25-26 μg/ℓ in 1969-70 to 6 and 11 μg/ℓ in 1979 and 1980, respectively. There were also considerable reductions in biomass and chlorophyll-*a* concentrations, and the transparency of the reservoir improved as well. There were changes in the types of algal species and their seasonal frequency, with diatoms becoming predominant. It was emphasized that the improvements were achieved by reducing phosphorus only and were independent of the input of nitrogen from the river (5 mg/ℓ as an annual average).

The invited discusser, Basalo (France), noted that there were other instances in which the removal of phosphorus has controlled eutrophication, but that the number of well-documented cases was limited and may not yet permit generalization. A few questions were raised by other discussers as to whether the Wahnback situation was a special case, or whether its methodology could be used elsewhere. The author replied that the ability to practicably treat the single major source of the phosphorus was the overriding factor.

In response to a question from Zunckel (South Africa) about costs, the author indicated that it would have cost considerably more to reduce phosphorus inputs at several other upstream points, and this would have eliminated only 70% of the phosphorus. In reply to questions about the relative impact of dissolved and suspended or sedimentary phosphorus on the eutrophication status, the author noted that there is still phosphorus in the sediments of the reservoir. However, this is now the principal phosphorus source and it is much lower *in toto* now that the treatment process has been instituted.

IV. CRITIQUE OF SESSION

Papers No. 3, 6, and 9 from South Africa dealt with the development and utilization of wastewater renovation technology for potable reuse and the chemical and toxicological assessments of the finished waters. They demonstrated the momentum and commitment of the South Africans towards treated wastewater reuse for potable water and the high state-of-the-art technology and science they are bringing to bear in this field. One impression from the discussions is that there is considerably more caution outside of South Africa than in it about the speed or necessity for potable reuse and the need to consider alternatives. One comment typified the South African philosophy; namely, that they judge the measured quality of the renovated water as being more important than its history.

Paper No. 12, an assessment of the economic impact of mineral pollution on public water supplies in an urban-industrial area of South Africa, although an apparently competent study, gave the impression of being a paper exercise dealing with impacts whose numbers were quite "soft." It did not attract a lively discussion.

Paper No. 15 on the effects of phosphorus elimination from a reservoir used for a public water supply was a well-presented, long-term study of an unusual approach to control eutrophication, namely by treatment of a river effluent. The focus of several of the questions were on whether this was a unique situation that lent itself to this approach. It appeared that the practicality of the situation was of greater interest than the limnological aspects.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Although research and development activities in the United States on wastewater renovation for non-potable use have been well underway for at least 20 years, similar efforts on potable reuse have been much more modest, cautious and recent. It does not appear that the technology and applied science in the South African efforts are more advanced than in the United States but that they feel the need and have proceeded rapidly in the direction of potable reuse. The possible significance of this South African work is that the demonstration of the practicality of these systems, including public willingness to drink the water, may help overcome the psychological barriers to potable reuse here. Also, their approach in evaluating the finished water rather than the nature of the raw source is at variance with longstanding United States thinking. In this country, it should be examined for its possible utility.

The paper on phosphorus removal from a river effluent to a water supply reservoir to control eutrophication is significant in its approach of not treating the sources to the river, but the river itself. Where correspondingly efficacious hydrological situations to control phosphorus or other chemicals may arise in the United States; this example might serve as a stimulus to examine river effluent treatment as a practicable alternative to source control.

I. SESSION

A. Day: Tuesday, March 30, 1982
Hall: C
Time: 9:00 a.m. to 12:30 p.m.

B. Theme of Workshop: "The Use of Mathematical Models" (Theme 1)

Convenor: A. Gerber (South Africa)

Panelists: A. L. Gameson (United Kingdom),
J. L. Marivoet (Belgium),
T. O. Barnwell (U.S.A.) and
A. James (United Kingdom)

II. REVIEWER

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III. DESCRIPTION OF WORKSHOP PAPERS

A. Paper A: "Review and Background," by A. Gerber (South Africa)

The chairman opened the session with some introductory remarks which were confined to answering the following questions: (1) What is a model? (2) How is a model developed? (3) Why are models practical tools? (4) How are models misused? (5) What skills are required for successful modeling and what safeguards can be taken against their misapplication?

A mathematical model is a set of equations which, subject to certain assumptions, describes the physical, chemical, or biological processes of interest in the water body. The body may be a river, lake, estuary, coastal water strip, or groundwater. Model development requires a four-step procedure. The first is to gain an understanding of the system to be modeled. Second, the governing relations identified in the first step are translated into mathematical equations which approximate the behavior of and interrelationships between the various water quality parameters being considered. Third, a computational scheme is developed to solve the set of equations. The fourth step entails validation of the model. This attempts to make a general model unique to a particular water body, and also establishes the level of confidence in the model results. The first part of validation is calibration which involves adjustment of model coefficients until the computed results match those from the historical behavior of the system. The second part of validation is verification during which the model is tested against several other independent data sets. If results compare favorably with observed conditions, the model is considered verified.

There are several characteristics which make models practical tools. First, they provide a means to solve extremely complex water pollution or water quality problems and can give information which is otherwise unobtainable. Water quality data give only a synoptic view of the combined influences of all factors affecting the system, and it may be impossible to predict water quality conditions accurately with analysis of the statistical properties of historical data alone. Second, the models are available to anyone in the water quality business. The tools are where they belong: in the hands of those doing the local work where the problem areas exist. Third, a numerical code and data are a means to transfer information as to how a problem was solved.

Models are misused in many ways, three of which were highlighted. First is overkill and selection of the wrong model, second is inappropriate prediction, and third is misinterpretation. The temptation to use the most sophisticated model is often due to lack of input data, perhaps causing the investigator to feel that what is lacking in data may be rectified by use of a sophisticated model. One should be cautious of choosing a model with audience impact or public relations in mind. An overly sophisticated model is the wrong model, and one needs competence, not only to use numerical models, but also to know when not to use them. Numerical models are the most powerful tools available for solving water quality problems, and the chief drawback of any powerful tool is that even slight misuse can bring disastrous results. Many modelers seem to believe that numerical models can be calibrated to predict future water quality trends regardless of the input data. This is false, as the ability of a model to duplicate past conditions does not guarantee its ability to predict future ones. The success of a calibration is directly proportional to the amount of reliable input data and the skill of the modeler. Perhaps the worst possible misuse is blind faith in model results. Calculations that contradict normal intuition may be the result of data entry error, an error in the program, or misapplication of a model to a situation for which it was not designed. If interpretation of the model results is not coupled with a conceptual understanding of the system under study, the whole exercise becomes not only a waste of time and money, but a threat to the profession in which it is applied. This is borne out when managers make broad reaching decisions about their water resources on the basis of poorly constructed and interpreted models. And when administrators distinguish good water quality studies from bad by assuming that the former are those in which the numerical models are employed. These actions can only produce untenable studies and management programs, and the end result may be a loss of confidence in both the modeler and his models. Models do not eliminate the need for data gathering efforts. Practical experience, judgment and common sense must be combined with the speed and accessibility of modern computers.

Finally, what skills are required for successful modeling and what steps can be taken to safeguard against misapplication? The modeler should have a firm understanding of:

1. The hydraulics of the water body under study and the factors influencing water movements;
2. The strengths and weaknesses of field data collection;
3. The theory of the chemical and biological processes being modeled;
4. The theory of numerical water quality models; and
5. The principles of sound scientific judgment.

As protection against the misapplication of water quality models, the following points are offered:

1. Does the modeler have sufficient background in modeling and the scientific discipline in which it is applied?
2. Is the proposed model compatible with the available data?
3. Is the proposed model compatible with the stated project objectives?
4. Has the proposed model been thoroughly tested and successfully applied to other field problems?
5. Have all the pertinent assumptions which limit the model been clearly understood and stated?
6. Is the model application an integral part of any data collection activity?
7. Are the predictions based on modeling a valid extrapolation of historical data?

B. Paper B: "Application to Estuarine and Coastal Waters," by A. L. Gameson (United Kingdom)

The principles underlying the mathematical modelling of parameters of pollution in estuarine and coastal waters were outlined in non-mathematical terms. Attention was drawn to some of the difficulties encountered--such as in assessing the inputs of relevant substances, evaluating coefficients of transformation processes, and ensuring that models can reasonably be used for predictive purposes. Two examples were given, one relating to dissolved oxygen in an estuary, the other to enteric bacteria in the sea. The application of models to the formulation of pollution control policies was reviewed.

Gameson (United Kingdom) initially stated the four terms of reference given to him for preparation of his paper. They were:

(1) For the benefit of non-mathematically trained participants, descriptive, rather than mathematical methods are required to show how models are arrived at. Accordingly, there are no equations in the paper.

(2) Application of models to show effects of discharges at different points to varying load.

(3) Show how models can affect policy decision. This proved to be a tricky assignment as it is generally difficult to find what has been the influence of a mathematical model on policy decisions. For instance, those seeing the simultaneous clean up of the Thames estuary over the last three decades and the advances in estuarine modeling that were made in the study of that estuary may well be excused for thinking that the cleanup resulted from the modeling. This is not so. No mathematical model was needed to show that the gross pollution of the Thames was attributable to the fact that almost all of London's sewage was discharged to the estuary with no more than primary treatment. The Thames would have been cleaned with no mathematical model even though the model is still used to provide a scientific basis for control of Thames pollution.

(4) Authors are requested to prepare papers with an international scope.

The various stages between the mathematical modeling and the formulation of pollution control policies were first outlined. The first stage is mathematical representation of water movements with a degree of accuracy sufficient for the ultimate purpose of the model. Next is the choice of the pollution parameters to be modeled. As perfection is unattainable, much of the art in modeling lies in knowing which corners may be cut and conversely where more experimental data are needed for the development of a scientific model.

The model must be shown to work satisfactorily. This requires that field data be used with inputs of all relevant substances, and that the water quality predictions and measurements must agree. Discrepancies may be due to imperfections in the mathematical representations of the process involved or to inadequacies in the field data. If field data are available for a wide range of environmental conditions, it will generally be possible to make satisfactory adjustments to tune the model to get an acceptable fit. But if, as may well happen with limited field data, the model is adjusted to give the right answers for the wrong reasons, it may give entirely misleading answers when used predictively. It is worth emphasizing that the predictive use of models is almost invariably extrapolative. They may be required for predicting the effects of new discharges, of altering the degree of treatment and point of entry of existing discharges, or of reducing the freshwater flow entering an estuary. For this reason, it is essential that the model be adequately verified.

At this stage, publication generally ceases. The scientist's work is done; he has shown that he has provided the authority with a management tool. The literature on verified models is notably less than that on unverified ones. In some cases the model is never applied as the management decisions could not wait for the modeling or the model is used to confirm the decisions already proposed or taken. In other cases, it is used to predict the efficacy of various alternative pollution control strategies, so that the most appropriate one can be selected. The readily available literature on the application of models is sparse. The concluding remarks on a number of papers indicate that the model described has reached the stage at which it provides planners with a means of assessing the effects of various water control management strategies. The management decisions resulting from the applications of models, however, are rarely published in technical journals. The managing authority is responsible to whomever funds it, but reports of its decision and the reasons for them will generally have a limited circulation.

It is evident that estuarine water quality models are extensively used in the United States, United Kingdom and Australia, but coastal water quality models are not applied to the same extent. Some models with wide range of applications to coastal and estuarine models do exist.

Gameson (United Kingdom) referred to some problems encountered with models with which he had been associated. There are problems in representation. For example, a coastal model described assumed that tidal currents run parallel to the shore and that the sea bed is horizontal, and specification of boundary conditions is difficult. A model need be no more complex than required by the use to which it is to be put. For example, if an estuary is well mixed, a one-dimensional model will surface. Two-dimensional models may be needed if there are marked variations in properties over the width or depth. The most complex situations may require three-dimensional models although the lack of adequate field data may obviate their use. Finally, there is dispersion; its representation is more difficult in the coastal than in the estuarine situation. Dye patches do not spread out radially from their sources even in the absence of wind. And the most suitable representation of diffusion will depend on the length and time scales involved. Thus different representations may be needed when considering a substance with a rapid rate of transformation and one which is almost conservative. The appropriate rate constants cannot always be readily evaluated, as is the case for bacterial mortality in the sea.

Another problem area is that of input data. Adequate data can readily be obtained for a single ocean outfall. There may be several hundred potentially polluting discharges to a large estuary, however, and sufficient data on these may be lacking. The chemist is concerned with concentrations in the discharge, the modeler with inflow rates. Diffuse sources are also uncertain: storm sewage overflows and rivers cause uncertainties in coastal waters. The effects of these on bathing waters are far greater than the same loads when discharged from a long sea outfall.

The third problem area is that of water quality data. More data are required for more complex models, and isolated intensive surveys may be inadequate. First, because the model may give either steady-state predictions which are unrelated to any particular survey or do not extend long enough. Second, the intensive survey may not have the transformation rates assumed by the model. For example, reaeration rates of estuaries can be substantially increased by a strong wind, and the rate of bacterial die-off in the sea can be increased by sunshine.

The final problem area is verification. This is essentially a compounding of all of the previous problem areas discussed. Model tuning may take months with the client already waiting for predictions. An ideal time to stop may be when the sensitivity analysis, taking account of all the possible model parameter uncertainties, shows that the uncertainties in the predictions are unlikely to lead to the wrong management decision. Although he likes this idea as a theoretical concept, it may not be a practical one. Coarse tuning may be adequate for a simple situation where the answers obtained are clear cut. Finer tuning may be needed if the implications are not clear or if the model is to be used for a variety of purposes.

Harold (South Africa) liked the emphasis on the need to tailor the complexity of the model to the complexity of the problem at hand, but wanted to make a strong case against oversimplification. He cited an example of an estuarine model used to predict changes in a harbor at Richards Bay. The model was incredibly oversimplified. The results were compared to those produced by a more complex model and found to be off by 200% to 300%. On the other hand, about a half million Rand were spent on a physical moving bed model which was equally incapable of predicting the effects in terms of tidal fluctuations.

C. Paper C: "Application to Rivers and Underground Waters,"
by J. L. Marivoet, F. De Smedt, A. Van der Beken,
J. Dirickx, and W. Van Craenenbroek (Belgium)

Mathematical models describing the water quality in rivers and groundwaters are derived from mass balances. For rivers, a one-dimensional transport equation is derived. Different methods of parameter estimation are considered and more recent techniques are introduced. For the application of water quality models to river management, two groups of models are considered: simulation and optimization models. As a case study, the Bedford Ouse quality models were described. Practical and theoretical applications in the United Kingdom, Canada, Federal Republic of Germany, United States of America and Belgium were discussed. For groundwaters, several applications of water quality transport models were discussed and their use in groundwater management was explained.

Marivoet (Belgium) presented the paper and confined his presentation to everything but groundwater applications. In introducing his paper, he referred to the use of mathematical models in quickly comparing different water pollution control strategies.

The development of a one-dimensional river model was then discussed. Two types of river modeling were distinguished: mechanistic models and "black box" models. Mechanistic models try to describe all the physical, chemical, and biological processes occurring. Black box models are much simpler, giving linear relations between inputs and outputs without attempting to describe the internal processes. A third intermediate model type is a "grey box" model, which is a black box model with some mechanistic components.

As an application of a mechanistic model, a model proposed by Knowles and Wakeford (1978) was discussed. This model described dissolved oxygen, biochemical oxygen demand, ammonia, and nitrate concentrations in a river. Eleven biological, chemical, or physical processes were included. Twenty-five model parameters are needed, many of which are difficult to estimate.

An example of the black box modeling technique proposed by Whitehead (1975) for the Bedford Ouse in the United Kingdom was discussed. This model described nitrate, dissolved oxygen, and biochemical oxygen demand. Just three rate constants and three lumped parameters were required, which can be obtained by statistical methods if a long-term series of water quality measurements are available. For good results, however, time-dependent parameters are needed, which can be obtained by techniques such as Kalman filtering.

For short-term predictions, black or grey box models are generally preferred. For long-term predictions, and particularly if large river changes are proposed, mechanistic models are mainly used.

A Belgian application of the use of models in decision making was then presented, based on the work of Nihoul and Smitz (1976), Nihoul (1979), and De Smedt, et al. (1981). The model was used to predict the quality of water extracted from a river-canal system in Antwerp. The river is polluted and does not satisfy drinking water criteria at low flows. The model permitted the water quality manager to decide on the use of water from storage reservoirs or canals, based on predictions of water quality parameters for each case. This is particularly useful during drought periods when the reservoir water must be economically used.

Practical examples of river quality modeling were given in the text from the United Kingdom, United States, Canada, and Germany. After the text submission deadline, interesting reports were received from Australia and the Netherlands.

Marivoet (Belgium) concluded that great restrictions were placed on model use in decision making by the poor results obtained with models that are improperly calibrated and tested. Confidence limits on water quality predictions should also be stated to allow the decision maker to account for uncertainties in predicted values.

Mathews (United Kingdom) noted that reference is made to the work his authority (Anglian Water Authority) is doing on river quality modeling. The main purpose of this work is to enable calculation of permissible qualities for 1120 sewage works and several hundred industrial dischargers in their authority.

To do this, the many uses of the river are defined and then associated with allowable contaminant concentrations. Users are assigned to each river stretch, and the most sensitive value of water quality parameter for that use is selected. This then forms the river quality specification to ensure that all the required and planned uses of the river are protected. The model discussed in the text is then used to translate the river quality specifications into permissible discharge limits. Practical applications and model development have proceeded simultaneously, and the model predictions are routinely used in planning.

There is a problem with ranking of priority of discharge problems, however. Therefore, a second, more subjective model was developed to produce an "index of discharge impact." The higher the index, the higher the priority of a scheme in the capital program. The point he wished to make was that models can be and are used in routine planning and in large-scale operations.

Briggs (United Kingdom) stated that his background was in instrumentation and control rather than in mathematical modeling, and as a consequence, he was probably more biased towards black and grey box models used in real time. As a practical user of models, he indicated the major reasons for model development are to obtain a better understanding of the regime or process; secondly, for day-to-day management purposes, for example, intake protection or process control; and finally for general management in real time, for example, flood warning. Models are also valuable in design of water and wastewater treatment plants when the model is not used on line and in planning for pollution control. In all of these applications, the model is only useful if it can be applied predictively, and the predictive precision depends on the degree of validation. At all stages of model development there should be continuing refining and tuning based on real-time data gathering if possible, or by careful interfacing of laboratory data into the model.

Because of recent advances in microelectronics, sensors, and computers, it is now possible to do this at reasonable cost. By a dual sensor approach it is possible to produce data of known and adequate precision. Briggs (United Kingdom) cited a computer control system in England which has operated for two years without failure. The system cost was about $150,000, and its use obviated the need to build a storage reservoir which would have cost more than $4 million. Modeling is now being applied to the data collected to control the treatment process.

Some details and results of instrumentation applications were then discussed. A new development is to measure heats of reactions by means of captive enzymes on thermistors, developed by Mossback and Nielson in Lund, Sweden. Sensors are available for detection of heavy metals, insecticides, cyanides and phenols.

The major point that Briggs (United Kingdom) made was that if we can measure online, and with reliability, the variables to which the model is most sensitive, then the model can be continually tuned and used predictively with much more confidence.

D. Paper D: "The Use of Water Quality Models in Management Decision Making," by T. O. Barnwell, Jr., and P. A. Krenkel (U.S.A.)

The use of water quality models in three management contexts is described: screening, planning, and design. Screening models are illustrated by describing a methodology applicable to large areas of land and another applied to a large number of chemicals. The application of models in a planning context is illustrated by a local planning agency's use in developing nonpoint source control strategies and by the federal government's use in assessing potential exposure to a pesticide. Development of design criteria is illustrated by summarizing the long history of model use to develop effluent limits in the Holston River basin (Tennessee).

Screening models are fairly simple and quick to use; they can often be implemented on hand calculators. They are intended to be conservative, and only to indicate potential pollution problems which should possibly be pursued further. Typical model designs for streams and rivers, lakes, and estuaries were discussed and the results of two applications, to the Sandusky River basin and the Chesapeake Bay watershed, were presented.

Planning models are more sophisticated and require considerably more effort to apply. Two examples of their use were presented. The first was to design pollution control strategies for the Occoquan River basin for the next 25 years. The second was to investigate potential risks to aquatic life of use of a pesticide in the Yazoo River basin. The results were used in negotiations between the U.S. Environmental Protection Agency and the pesticide manufacturer to change labeling instructions on the pesticide on how the farmers should apply it.

The planning model applications demonstrated two strategies. First, in the Occoquan, the modeling had an extensive data base, and the model was thoroughly verified. Second, in the Yazoo, the model was used to make estimates which would not otherwise be available, to demonstrate potential effects.

Design model use is probably the most common application of models in the United States. Typically, this would be to set discharge requirements to meet water quality standards. An application for the "seriously polluted" Holston River was discussed as an example. The model was used to investigate the effects of a wide range of management decisions. In hindsight, Barnwell felt that probably the same conclusions would have been drawn without the model use. Field studies showed that water quality was being protected, and the model showed that little more improvement could be gained from further treatment improvements.

The conclusions were that models were effective tools in screening, planning, and design. His experience was that results should always be confirmed by data or some independent analysis. Data is best, but not always available, so independent analyses must sometimes be used. A thorough and objective review should also be made.

Holden (Australia) said that it has been stressed that quite detailed data must be available in order that models be verified, otherwise users would doubt that the models are satisfactory. He wondered if Barnwell (U.S.A.) would comment on this with regard to this screening model. He noted that the rate of transport of the chemical through groundwater was assumed to be limited by the hydraulic conductivity of the soil and not by mass transport through the boundaries of the containment facilities; that soil sorptive capacity had been reached; steady-state concentration profiles had been achieved, and hydrolysis was the only degradation process considered in the groundwater. Does this mean that when applying the model to each chemical, one must go out and measure the hydraulic characteristics of the soils and assume that the soil is uniform? Does it also mean that biological degradation is neglected within the soil, and is it correct to assume that the only degradation process is hydrolysis? He would assume that many of the chemicals are not hydrolyzed at all. So it seems that there are a tremendous number of assumptions built into the model. Although bearing in mind that it is only a screening model, he would nevertheless be interested to know if data have been accumulated to see if the predictions are realistic. He would have grave doubts on this.

In response, Barnwell (U.S.A.) said that they had to assess many chemicals in a very short time. They did not neglect microbial degradation in groundwater; there was evidence that the microbial populations were very small. At that time, the main issue to be addressed was whether the chemical would be transported through the groundwater. It was felt that over a long time, because the groundwater movement rates were very slow, that it would take a very long time for a chemical to migrate even a hundred meters. So that either a chemical migrated or it did not. If a chemical hydrolyzed, the reaction rates were generally sufficient to degrade it. If it did not, it would move into the river.

A sensitivity analysis was performed to see if the model was sensitive to different movement rates and it was not. In certain cases, the chemical would degrade but not hydrolyze. The assessment was designed to be conservative. If there was a potential problem, they wanted to predict it. Sometimes the models fail totally, and the results must be viewed skeptically. The analysis did not end there as they were trying to identify chemicals for which additional data was needed; they cannot economically collect data for every situation.

E. Paper E: "Mathematical Modelling of Estuaries and Coastal Waters," A. James (United Kingdom)

The paper was concerned mainly with the modeling of physical aspects, but his presentation was more oriented to chemical and biological aspects. An estuarine system has physical hydraulic characteristics and is subject to waste loads. Together these constitute the decay system, which interact with the reaeration system to determine the level of dissolved oxygen in the estuary. Normal estuary models take these two inputs and predict oxygen levels. The oxygen consumption rate is pseudo-first-order, whose rate is determined by the organic matter concentration in the water. Reaeration is determined by the saturation deficit and is rarely directly measured. The decay is also usually assumed to be homogeneous throughout the water column. In the Tyne estuary, however, less than half of the 114 tons of ultimate oxygen demand discharged daily remains in solution or suspension, and the rest settles on the bed. It exerts an oxygen demand in a different way than if it remained in suspension. These two demands need to be considered separately in order to make a predictive model.

The nitrogen cycle was then considered as this can impinge on the oxygen regime in two ways. In an aerobic situation, discharged ammonia may be converted to nitrate in the water column or bed. If we are trying to predict oxygen levels due to waste load reductions, the kinetics of nitrogenous oxygen demand must be included, as this could become the dominant future oxygen demand. This is not always the case, but current understanding is sufficient to include nitrification and nitrification kinetics should be included. Few models can predict conditions in anaerobic estuaries, but, as this situation often occurs, this would be a profitable area for increasing modeling capability.

Another oxygen sink is connected with plankton. From the modelers point of view it is fortunate that there are very few things living there. Plankton can be significant, however, and not much is known about their dynamics in estuaries, which, although complex, may sometimes need to be included.

Although estuaries and coastal waters are lumped together by modelers, their similarities are at best superficial. The varying salinities in estuaries makes the development of significant populations difficult, a situation which does not arise in coastal waters. In coastal waters, dissolved oxygen is usually not of interest, due to the mcuh better dispersion and dilution. So coastal models should be completely separate from estuarine. Coastal models are more concerned with amenity and secondly with bacterial concentration. The gap is felt to be the concentration on pipelines. The principal pathway of wastes into the sea is by means of estuaries, and it is surprising that there is not more modeling work concerned with dispersion from estuaries.

In predicting bacterial concentrations, initial dilution, gravitational plume spreading, subsequent dispersion due to wind, tidal currents and residual currents, and also die off must be included. Only limited success has been achieved in attempts to model this combination. Die off is much less understood than is initial dilution.

Ecological models are less developed than engineering ones, but help our understanding of the interactions and have a useful role to play. Briggs (United Kingdom), the official discusser, said that the main difficulty is in validating the models, yet it is essential to verify the mathematical models by field work. If not, we lose credibility.

There are two model types: (1) A *priori*, which are models established intuitively and by common sense, but which are often wrong; and (2) Scientific models based on measurements. In showing how much we must be very careful with *a priori* models, he related a story of an economics model used 30 years ago. The problem was to dispense credit to different municipalities. The model used 30 parameters, all of which added to zero, and so everyone was happy with the money distribution as everyone got the same amount. The model merely verified this. The message is to use scientific models but to verify the approach independently.

Kuznia (Federal Republic of Germany) pointed out the use of models for on-line control. The model can resemble the plant to be controlled, and, if feedback is added, stability can be ensured. For example, they made a nonlinear model for dissolved oxygen control simulation in aeration basins. The benefit of this procedure was that they very quickly and efficiently came to the correct coefficients for control, which were much better than the normal proportional differential controls. He felt that simple models and models which can be simulated first for control should be considered before putting a control into effect.

Alexander (South Africa) got the impression that, internationally, models are custom built. Most modelers feel it is easier to build their own model than use an existing one. The state-of-the-art in South Africa is that there are some good rainfall runoff models, well documented and used. There are some recently developed rainfall runoff salinity models, and rainfall runoff salinity economic models are needed for evaluation of management options. For research problems, they look at a suite of models and choose the most appropriate one. Examples are to determine the effects of weather modification on runoff and on eutrophication above dams. He added a basic message: If models are used for management decisions, then it is imperative that the user agency be involved in the model development.

Gerber (South Africa) agreed that ideally technical experts trained in the use of models should be a part of the management organization responsible for solving the problems to which the model is applied. There is then a great incentive for the expert to use the model properly.

Gerber (South Africa) commented on communication problems between management and technical personnel which is a widespread source of difficulties in model applications. The first problem is model credibility: the lack of confidence of managers in models as decision making tools. This may be because modeling is becoming increasingly sophisticated and has developed rapidly. Many managers are unfamiliar with modeling techniques and have no feel for applications to their particular problems. While managers do not need to know all the technical model details, they do need some appreciation of the framework and inherent limitations and assumptions of the models. This may lead to initial uncritical enthusiasm which can lead to disillusionment and mistrust. The manager may think that models are mysterious and even threatening to his job.

The fault may also be with the professionals who build and apply models. In particular, overselling of models and overmodelling: e.g., the application of a model too sophisticated for the job at hand. These can both lead to managerial disillusionment, and to the impression that models do not produce efficient reliable results for decision-making purposes. The output must also be presented in meaningful way, and the uncertainties should be presented. Graphics and other displays might be very useful. The modeler must be attentive to managerial needs, and avoid jargon such as dispersion coefficients which are meaningless to the manager. Interactive participation between managers and modelers at all stages is highly desirable.

Briggs (United Kingdom) replied to Gerber (South Africa) from the water treatment facility standpoint. One reason that models are not more applied is that the nature of the decision-making process is an imprecise one. What one would have to do is convince the manager that if he had more and better quantified data in front of him, his decision making would be less imprecise. Second, there seems to be a boundary between those people managing the facility, and those who might suffer from a mismanaged facility. If there was a subjective table to tell the manager what would happen, for example, if so many tons of BOD went out on Tuesday at 2 p.m. instead of spread over Wednesday and Thursday. And if he knew what storms or toxicants were approaching his works, it would be relatively simple to make decisions such as: should I accept this sewage straight into my primary tanks and if I do will I run the risk of killing the bacteria in the aeration basins, should I step feed and put that material elsewhere, and should I pull the sludge back out of the settler into the aeration tank front end to protect the sludge. If we model all these things, we can make short-term gains to attack acute difficulties, but seldom make an overall gain in total performance. That use of modeling is not pushed as well as it might be.

Garber (South Africa) stated a problem exists with accessibility of models to users. He wondered whether top priority should be given to making existing models more accessible. This would entail improving the quality of information on models and making this information and the models more available but also in improving the training of those using the models. He wished to highlight two areas: documentation and distribution.

Proper documentation means a model description, a listing of the code, and a users manual. Documentation is not typically listed in a consistent format and is scattered throughout the literature. Consequently, people wishing to use models are often not aware of what models are available nor where to find this information. Documentation should provide an easy means for anyone to run the model, yet this is not usually the case. The reason for this may be that this is the last step in modeling, and often not immediately necessary. Funds may be exhausted at this time, and there may be little training or interest of the modeler in preparing this documentation. There may also be little incentive for him to document, and he may be reluctant to expose particular features, uncertainties and assumptions in his model.

It is not in the interest of private firms to distribute work developed for clients. Universities often develop the poorest documentaton. Perhaps a prerequisite to funding by an agency should be adequate documentation of the model produced.

Concerning model distribution, Gerber (South Africa) felt a well documented model should be publicized and distributed to be of value. There is no presently available service to coordinate this. It seems necessary to provide a control facility, or clearing house, which would be responsible for collecting information on models and to actively engage in a program to make this information available to users. This should be on an international basis as model development is expensive, and unnecessary duplication of effort could be avoided. This is particularly needed by developing nations which have no modeling expertise of their own.

Barnwell (U.S.A.) responded to Gerber (South Africa) by saying that a report responding to many of his concerns in terms of model accessibility and user training was about to be published. An organization has been formed, called the center for Water Quality Modeling, to provide documentation and code for a limited number of models. A users group also exists which has a mailing list of about 1000 people. If anyone wishes to be added, they should contact T. Barnwell, U.S. EPA, Athens, Georgia, U.S.A.

IV. CRITIQUE OF SESSION

The session contained more generalities than specifics, and it is doubtful that the "state-of-the-art" was adequately represented as many recent developments were omitted. Discussion of the role of models in decision making was also sparse, although this is probably due to the difficulty in finding out just what the role of a model was in a particular instance. The value of the session probably lies in the compilation of the many references of the papers, but particularly in the discussion of modeling pitfalls and methods to avoid them.

Gerber (South Africa) expressed very well the pitfalls of model misuses, communication problems between modelers and decision makers, use of oversophisticated models, and need for adequate verification. His discussion of these problems, the effects of poor quality modeling on the profession, and steps to obviate them should be read by everyone concerned with mathematical model use. Many of his points were echoed by other authors, particularly the need for adequate model verification by field data or independent analyses.

It is apparent that models are now routinely used in some decision-making processes. Most of these appear to be in rivers, particularly "black box" models used in conjunction with real time data collection for plant control. Mechanistic models are also used to identify highest priority discharge problems or areas which should be studied further. In some cases, however, the models played no role in the decisions made; the decisions were made without them.

River models are most commonly used, followed by estuary models, and, least of all, coastal models. Groundwater was not extensively discussed and lakes not at all. Presumably, river models are the most common because rivers are usually one dimensional and easiest to model, and, therefore, the predictions are the most reliable. Models are unlikely to be extensively used in decision making if their predictions are not reliable. It is worth mentioning that some believe that two- and three-dimensional models are still in the research stage, and even two-dimensional models can only sometimes give useful results when applied with care.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The use of models in decision making for solving U.S. water pollution control problems could be enhanced by requiring that confidence limits be stated along with model predictions; that the appropriate model be used (i.e., not too complex or too simple); that the user agency be included in model development; and that adequate model validation be proven. It is not obvious how this can be done, but tightening the requirements of pollution control agencies would help. Although this seems contradictory to the current mood for less regulation, it will be necessary if modeling and the profession are to be credible in the future.

More research in the area of "black box" models with real-time data would be desirable. It seems that presently these models are more used in Europe than in the U.S. Research in modeling the chemistry of anaerobic estuaries is also suggested. Finally, establishment of a clearing house would aid in avoiding duplication of effort and could provide a common pool of information.

I. SESSION

A. Day: Tuesday, March 30, 1982
Hall: C
Time: 2:00 to 5:30 p.m.

B. Theme of Workshop: "Oil Pollution in Marine and Freshwater Environments" (Theme 2)

Convener: N. King (United Kingdom)

Speakers: N. King (United Kingdom), A. D. Read (United Kingdom), M. T. Westaway (United Kingdom), K. Poppinghaus (Federal Republic of Germany), R. B. Clark (United Kingdom), and F. Berne (France)

II. REVIEWER

A. Name: Lawrence H. Keith

B. Position and Affiliation: Chemistry Development Coordinator
Radian Corporation
Austin, TX

III. DESCRIPTION OF WORKSHOP PAPERS

This session was a state-of-the-art workshop and the formal papers presented were for the purpose of introducing a topic for discussion. King (United Kingdom) gave a brief overview of the topic area. This, in turn, was followed by presentations of Read (United Kingdom), Westaway (United Kingdom), and Poppinghaus (Federal Republic of Germany), after which discussions of those three presentations were entertained. The last two presentations were made by Clark (United Kingdom) and Berne (France), after which discussions of those two presentations were entertained. Then all the topics were opened to discussion. In the interest of clarity, discussions involving each of the five topics are presented after major points of the respective topics have been summarized.

Read (United Kingdom), in a paper entitled "Legal and Administrative Control Aspects of Oil Pollution," discussed wide-ranging aspects of both the international legal problems and the various sources of oil pollution with their current pollution control meaures. He focused on the often ignored but increasingly significant problem of pollution from lubricating oils. He estimated that about 1% of all petroleum production ends up as various lubricating oils. Furthermore, half of these are not consumed and therefore ultimately must be disposed of. The problems with trying to recover and recycle these oils are that they (1) accumulate in relatively small amounts; (2) are widely distributed and depots may be in remote areas; and (3) are contaminated with numerous degradation products, preservatives and special additives. The attempted solution to this problem in Germany is to subsidize the collection costs; while in France it is to license the disposer and to control the prices paid for these waste oils.

Rivas (South Africa) questioned whether the levels of atmospheric pollution would be increased by burning lubricating oils. Read (United Kingdom) replied that increasing costs of oil makes the burning of waste lubricating oils more attractive, and to help counter this trend, Germany and France enacted the above-mentioned laws. Westaway (United Kingdom) commented that significant contributions to hydrocarbon emissions in air would occur only if oil combustion was incomplete; a more important concern is the potential for heavy metal pollution. The solution to one problem can therefore be the cause of another problem.

With respect to the international law aspects of the paper by Read (United Kingdom), the main concern of the audience was the low probability of enforcement. He allowed this was true in open seas but international and national laws can be enforced in harbors and around offshore oil platforms. He suggested increasing the percentage of ship logs versus cargo that are checked and preparing "black lists" of offending vessels; segregated ballasts would also help. Heynike (South Africa) asked who had responsibility for treatment of ballast tank wastes. Read (United Kingdom) replied that it was the obligation of each country to provide port treatment facilities for ballast wastes. Furthermore, if the facilities are full and cannot take the ballast waste or if there are no facilities for this, then the oil tanker's liability ceases and it can dump the whole ballast tank. This aspect of a nation's port liability is widely known. About 50% of the countries that have oil tanker ports are ratifying a 1978 international protocol and this should help the situation. Of course, this still leaves half of the involved countries that do not subscribe to minimum rules regarding oil pollution.

Westaway (United Kingdom), in a paper entitled "Sources of Petroleum Hydrocarbon Inputs to the Marine Environment," listed the most significant sources as natural seeps, offshore oil production, marine transportation, coastal industrial effluents (including but not restricted to refineries), the atmosphere, and urban run-off. Most of these are point sources with the result that the hydrocarbon inputs are unevenly distributed in the seas. He also made the strong point that the environmental impact of these inputs is not necessarily proportional to the amount of hydrocarbon input to the oceans. Rather the environmental impact is dependent on several other factors including the location of the discharge, the type and concentration of oil, and whether the discharge is continuous.

Heynike (South Africa) requested more specific information on sources of hydrocarbons from the atmosphere. Most of these hydrocarbons are believed to result from unburned emissions from vehicle exhausts. Lesser contributions may also come from volatilization of hydrocarbons from gas stations, refineries and storage tanks. Another significant source may be biogenic origins from trees and plants. The mechanism of their input to the oceans is through rain, dust particles and similar transport modes.

Poppinhaus (Federal Republic of Germany) presented a paper by Luhr (Federal Republic of Germany) entitled "Economic Aspects of Oil Pollution." Although cleanup costs associated with an oil spill can be ultimately calculated with reasonable accuracy, costs from destruction of the ecology of an area is almost impossible to estimate. The latter is subjective and depends on differing economics, geographical, hydrological and marine conditions. One generalization that can be made, however, is that oil spillages on the high seas cause less damage than those near shorelines. Another generalization is that the bigger the oil tanker, the greater will be the loss of oil in an accident. However, the frequency of accidents is also less with bigger tanks than with smaller ones.

During the discussion period, the feeling expressed by several was that supertankers were not desirable. However, panel members pointed out that although the impact of a supertanker accident was very large, their frequency was much less. Given that most, if not all, transport accidents ultimately are reduced to causes from human error, then it seems that the only choice lies between fewer but greater accidents or many more but relatively lesser ones. There was no consensus for either unfortunate choice.

Clark (United Kingdom), in a presentation on "Biological Effects of Oil Pollutants," made the point that often the reduction in population of animal or plant species around a major oil spill area is no greater than the natural fluctuations of some of these species. Oil pollution from spills at sea so far has not permanently reduced any plant or animal populations. Furthermore, the marine environment is subject to wild and erratic natural fluctuations of species populations. Therefore, these population dynamics must be taken into account in assessing overall ecological damage. These population dynamics also make it difficult to assess when ecological recovery is "complete" in a spill area.

One area, however, that does appear to be ecologically sensitive to damage from oil spills is that of coral reefs. Another question of ecological significance involves repeated (chronic) spillages of oil in an area. These two aspects may be more significant from lasting biological effects than the highly publicized oil spills that involve the temporary demise of biological populations in limited areas.

The question of taste contamination of fish from chronic pollution was raised. Clark (United Kingdom) replied that economically speaking, fear of tainting has a greater effect than the actual tainting. Bartlett (South Africa) returned to the subject of other biological systems besides coral reefs that are critically sensitive to oil pollution. Clark (United Kingdom) felt that another sensitive area consisted of the artic ecosystems which are sensitive because of their very long recovery times. Loy pointed out that another critical factor for biological recovery/repopulation was the need for neighboring communities and that without their presence, it would not occur. An additional factor that may be critical is the absence of repetitive oil spills in an area attempting to recover. Clark (United Kingdom) agreed with both statements and pointed out that the Britany Coast is an example of an area being seriously affected because of repeated oil spills.

Berne (France) presented the final paper entitled "Physical-Chemical Methods of Treatment for Oil-Containing Effluents." The basic principles and advantages/disadvantages of the use of cationic polyelectrolytes, dissolved air flotation and various filtration methods were summarized.

Tramier (France) raised the concern of adequate physical-chemical treatment of offshore oil platform wastes. Berne (France) said that dispersed oil flotation methods can reduce oil to about 200 ppm. Emulsions, however, may be common problems because of abnormally high suspended solids and cold water temperatures. Cationic polyelectrolytes can be used with success with these oil wastes.

Harley (South Africa) requested some discussion on the problems of removing oil from contaminated groundwater sources. Berne (France) replied that aromatic hydrocarbons are always found as remaining compounds in water contaminated by oil and that they can be efficiently removed using activated carbon. Pentz (South Africa) commented that a knowledge of the area hydrology is necessary because the best way to treat contaminated groundwater usually is to pump it up, remove the oil, and then pump it back. He also noted that in the United States, bacterial growths have also been injected to remove oil by metabolism.

King (United Kingdom) closed the session with succinct points from each presentation: (1) The primary concern of the legal and administrative control aspects is to make existing international agreements more effective; (2) in considering sources of oil pollution, it is also important that its effects be considered as well; (3) controversy still revolves around whether it is best to use smaller (and more) tankers or large (and fewer) supertankers with respect to economic and environmental effects of accidents; (4) in considering the effects of oil pollution, one must not underplay the effects of local problems; and (5) available abatement technology for treatment is still advancing and improving.

IV. CRITIQUE OF SESSION

Oil pollution in marine and freshwater environments continues to cause serious problems. In addition to the usual sources of oil pollution, it appears that specialized refined oils will become increasingly significant problems in spite of their relatively low volumes.

Enforcement of existing regulations regarding oil pollution is sometimes difficult. Not all nations ascribe to these international laws and, among those that do, their enforcement is uneven. This is sometimes caused by complications such as lack of equipment in ports to handle spilled oils. There is probably a general lack of understanding among most technical people for the economic and legal complications that can beset the prevention and cleanup of oil spills.

There is virtually no way that the economic aspects of an oil spill can be estimated. Cleanup costs can be estimated but not the costs associated with ecological damage. The latter are not only difficult to find and quantify but are also usually subjective. An ongoing controversy is whether it is better to use smaller tankers and suffer from more oil spills because of increased numbers of shipments or to use supertankers and suffer from fewer but larger oil spills.

The natural population dynamics of species destroyed by oil spills must be considered in order to keep incidents in proper perspective. Public communications tend to focus on what appear to be catastrophic destructions of species populations. Most of these are able to recover within a few years except for Artic populations, coral reefs ecosystems, and those subjected to multiple insults.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

One area where American technology can be brought to bear is a greater understanding of pollution resulting from special refined oils. Alternatives to dumping probably can be found that will make collection and recovery of these oils viable. This is a research area that has not received much attention in the past.

Research activities that make oil pollution cleanup faster, easier and cheaper will gain acceptance and wide use. Efforts to improve present technology could result in large future benefits. Background studies on natural population dynamics and the major contributors to speedy recovery of various ecosystem species will be useful for evaluations and recovery plans when dealing with future oil spills.

Physical-chemical recovery and cleanup methods still need research to understand their mechanisms and to improve upon their efficiency. Although this research has enjoyed significant funding in the past, its fruits have justified additional funding in the future in order to improve their cost effectiveness and efficiency.

I. SESSION

A. Day: Thursday, April 1, 1982
Hall: C
Time: 9:00 a.m. to 12:30 p.m.

B. Theme of Workshop: "The Economics of Water Pollution Control and Research" (Theme 3)

Convenor: G. Rincke (Federal Republic of Germany)

Panelists: J. A. Lusher (South Africa), G. Rohlich (U.S.A.), C. Lefrou (France), K. Poppinghaus (Federal Republic of Germany)

II. REVIEWER

A. Name: Carmen F. Guarino

B. Position and Affiliation: Past President, Water Pollution Control Federation
Washington, D.C.

III. DESCRIPTION OF WORKSHOP PAPERS

A. Paper A: "Review and Background," by G. Rincke (Federal Republic of Germany)

The subjects addressed were: (1) Why economize?; (2) What methods are available?; and (3) How these methods can be applied? To improve the decision-making process and to accentuate the importance of water pollution control, it must be recognized that cost reduction is not the only objective. There are other important considerations such as the health factors and the social usefulness of water resources.

B. Paper B: "Funding Water Pollution Control in South Africa," by J. A. Lusher (South Africa)

A major portion of this paper dealt with the South African Water Act. The objective of funding was to obtain the required funds and to provide for properly qualified and trained personnel. South Africa has been innovative, but more innovation is the key to economy in the water and waste treatement field. Full use is not being made of available data or the advantages of using computers.

The matter of who pays is a complex issue and one should refer to previous symposia in South Africa specifically dedicated to this subject. The proper charge requires a complex formula and should take the following into consideration: (1) What is fair and who has the ability to pay? A study of the cost of charges versus operational and capital costs in South Africa does not show a proper balance; and (2) It is easier for local agencies or government to increase a charge to industry? It is easy for industry to add this cost to the products they produce. It is much more difficult for local agencies and government to increase costs of water and waste treatment to the local citizenry.

C. Paper C: "Funding Water Pollution Research," by G. Rohlich (U.S.A.)

Because of the many factors involved in improving the environment, it is difficult to determine the effectiveness of money spent with accuracy. However, it is possible to make reasonable estimates of funding of water pollution research.

Examining research funding from 1960 to 1975 shows a decrease by the United States government of 15%. During the same period, United States industry increased their funding by 14%. Funding from universities, colleges and other non-profit institutions which form a small percentage of the total spent, has not changed appreciably since 1960. Suprisingly, even though construction funding has increased almost ten-fold since 1969 as compared with 1979, EPA funding, the major agency responsible for research, has remained constant.

The National Research Council recommended that water quality protection and control be given a high priority in federal research programs. They specifically gave priority to the significance of trace contaminants to human health, wastewater treatment research, water purification research, improved analytical methods and detection, enumeration of viruses and other infectious agents and monitoring of chemical contamination.

The Federal Government of the United States, at the present time, has been reducing their expenditures in research. This indicates a need for research funding from other sources such as the private sector.

D. Paper D: "Balancing Benefits and Expenditures in Water Pollution Control," by C. LeFrou (France)

Water pollution control is an economic necessity due to the need for adequate water resources in urban and industrial development areas. The economics of pollution control vary from area to area depending on many factors, including, but not limited to, demand and availability of resources. The cost per inhabitant is reasonably constant. The building of a sewage treatment works costs approximately 150 to 800 francs per inhabitant. The building of a sewage network costs about 3500 francs per inhabitant and individual sewage systems cost 300 francs per inhabitant.

The management of water resources and water pollution control has many variables ranging from collection of data to the management and execution of abatement programs. It is more economical to avoid pollution than to treat waste. Benefits to be considered are: fishing, swimming, boating, water fowl, hunting, hiking, picnicing, camping, nature observation, health, household benefits, industrial treatment costs, and commercial fisheries.

There are several methods used to evaluate benefits from water pollution control, as follows: speculative, aggregate, and methods applicable to particular sites. The speculative method estimates benefits by the use of mathematical relationships. The aggregate method uses statistical data coefficients to determine benefits in large areas. The third method; that is, the method applicable to a particular site, has its basis in surveys and polls of the involved users.

A determination of benefits varies from country to country, area to area, and site to site. There are many methods and techniques. Choosing the best method involves careful and extensive research and, finally, good judgment.

IV. CRITIQUE OF SESSION

In comparing funding problems, needs for funding, and sources of funding from the different locations in the world, it appears that the problem is somewhat the same; that is, none of the agencies indicated that they had sufficient funding or that they were able to devise a suitable, acceptable formula for obtaining funding. Whether one discusses these problems with the worker in Australia or in France, obtaining the necessary funding has been difficult. What was not brought out in the papers was the basic underlying reason for the difficulty in obtaining funding. Considering that people spend far more for less important resources, there seems to be an undercurrent reasoning that clean water is a God-given resource and should be cheap.

The papers focused on the essence of the meeting: the state-of-the-art economy will be achieved by using the best available knowledge and properly qualified personnel.

There was considerable controversy concerning the charging for water and sewage services, not just based on use but ability to pay. The ability to pay is further complicated by defining industry as the most likely user to pay for needed funding.

It was also clear that cost/benefit calculations are still difficult and, in the final analysis, require considerable judgment in deciding which method to use. The South Africans, as in many other areas of water resources work, have contributed greatly to the study of economics in managing water resources, and this information can be found in the symposia held in South Africa over the last several years. It would have been useful to have expenditures reported in the South African and French papers as was reported in the United States paper.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

To begin with, the papers echo the funding problems that are being experienced by the United States. It would have been useful to know if there were federal subsidy and to what extent. This would help the United States, particularly at this time, since we are struggling with the phase-out of the Construction Grant Program.

Observations in the foreign papers concerning who is to pay and how much was interesting. The fact that some feel that industry, since it has the means to pay, should bear a larger portion of the expense of managing water resources is a case in point. If the foreign papers reported the activities in the respective countries accurately, then it appears that the federal government of the United States does do considerable research.

Foreign papers did not uncover any new areas which were unknown to United States researchers. The contribution of this session was to obtain insight into the problems experienced by foreign agencies and perhaps to obtain some comfort in seeing that their problems are similar to those of this country. The papers, in general, indicate that we must be more efficient, but this efficiency, rather than coming from some major breakthrough, will come from hard work by capable people using existing data and knowledge. This, coupled with the research priorities recommended by the United States National Research Council, goes a long way towards outlining our work for the next several years.

I. SESSION

A. Day: Thursday, April 1, 1982
Hall: C
Time: 2:00 to 5:30 p.m.

B. Theme of Workshop: "Technology Transfer" (Theme 4)

Convenor: S. H. Eberle (Federal Republic of Germany)

Panelists: J. Sidwick (United Kingdom),
C. Guarino (U.S.A.),
P. E. Odendaal (South Africa),
M. J. Pieterse (South Africa),
J. Bernard (France)

II. REVIEWER

A. Name: Aharon Netzer

B. Position and Affiliation: Professor of Water and Wastewater Engineering and Environmental Sciences
The University of Texas at Dallas
Richardson, TX 75080

III. DESCRIPTION OF WORKSHOP PAPERS

A. Paper A: "Review and Background," by S. H. Eberle (Federal Republic of Germany)

Eberle (Federal Republic of Germany) gave the introduction and the opening remarks to the session. In his opinion, one of the most important problems in wastewater process design is scaling, both scaling up and scaling down. The problem of scaling is not new and engineers all over the world have struggled with it. With present advances of wastewater engineering, most plant and research engineers cannot handle all technical aspects of process scaling and need the help of an expert.

A great deal of technology transfer is needed in order to comply with new problems in wastewater treatment and the development of new technologies. The logical approach to solve current scaling problems in wastewater engineering is first to define the problem, then to search the literature for possible solutions, and when all the available information is on hand to select the most appropriate technology. The next steps are laboratory-scale experiments, then pilot-plant scale experiments, followed by construction and operation of a demonstration plant including cost evaluation. Only after that should full-scale plant operations be implemented.

The author gave details of manpower, money and time frame involved in each state. In Germany, it takes from five to seven years from the definition of the problem through the stages of literature survey, identification of possible solution, laboratory-scale experiments, pilot-plant scale experiments, demonstration plant and implementaton of the solution with full-scale operations.

B. Paper B: "Scale-Up Problems," by J. Sidwick
(United Kingdom)

Sidwick (United Kingdom) discussed problems of scale up of wastewater treatment processes from bench-scale to pilot-scale and from pilot-scale to full-scale. In his opinion one of the main problems in scale up is "technology transfer." From the research laboratory to the full-scale operating plant there are a lot of steps which are usually taken by a number of people. We not only have the problems of transferring the technology itself through these various stages, we also have the problem of insuring that the knowledge acquired at each stage is fully passed on to those undertaking the next stage. Therefore, "scale-up" is both a human communication transfer problem and a technical transfer problem.

Scale up can start with the researcher who has a good idea and who develops it in a simple way in a test tube and later in bench-scale work. The scientist will probably publish his results. If his work looks promising, he is likely to build bench-scale pilot plant equipment in order to simulate more realistically the full-scale situation. Assuming that his work has been successful, he will have published his findings. If the findings meet a need, then practical engineers or operators will take them and apply them. Usually this application will first be on a larger pilot-scale. Sometimes, modifications are made to an existing full-scale plant to allow it to be operated experimentally. This second stage of development may, or may not, involve the original researcher. Finally, the process may be accepted as being valid and may be widely introduced on full-scale. The process has to be proven, refined and shown to be practical in real situations with real operators. There is an absolute need to insure that findings established in each stage are communicated in full to the next stage. Sidwick (United Kingdom) encouraged the scale-up engineer to maintain close liaison and to consult with the original researcher and the operators who can spot difficulties and suggest solutions.

Sidwick (United Kingdom) referred the audience to his paper for more information about pilot-plant scale proving of process design, pilot-plant scale operation to demonstrate process suitability, pilot-plant scale operations to allow full-scale cost estimate, mathematical modeling and its role in scale up and real life problems to try to put scale up into perspective technically.

Sidwick (United Kingdom) concluded from his paper that: (1) the researcher working at his bench to produce academic and theoretical explanations of why things happen can offer the key that will unlock the door of the more pragmatic; (2) the bench scale work of the researcher can often not be scaled-up with the reliability often implied; (3) bench-scale plants usually need to be developed into a reasonable pilot scale to simulate the full scale; and then it does not always simulate properly; (4) in the final analysis nothing is as good as full-scale operation and, often, the interpretation of less-than-scale work is heavily influenced by full-scale operational experience; and finally, (5) the researcher generates the concepts that may or may not work in practice: the designer and the operator will see if they do and will learn much more about the mechanisms of the process.

Scale up problems can be considerable, but the blurred transition from bench-scale, to pilot-plant, to full-scale is inherent in the logical development of processes from academic aspiration to operational reality.

There was only one comment from the floor by Bricks (United Kingdom) about the "not invented here syndrome." Bricks (United Kingdom) agreed with the need for information to be totally transferred at each stage during technology transfer, but asked, "What do you do with the block that occasionally occurred with the recipient?" Bricks (United Kingdom) gave an example of the lack of communication between industry and consultants in England. Sidwick (United Kingdom) agreed that this is a serious lack of communication which costs the public a lot of money unnecessarily.

C. Paper C: "The Role of Consultants," by W. Eckenfelder (U.S.A.); presented by C. Guarino (U.S.A.)

In consideration of the role of consultants in technology transfer, it is important to consider two separate cases, municipal water pollution control and industrial water pollution control. The industrial case would consider industrial wastewater works with large industrial inputs. It is not feasible to apply results obtained for biological treatment of municipal wastewater to most industrial categories. Technology transfer needs to be restricted to wastewaters of similar chemical composition.

With respect to nitrification, the large amount of data presently available for municipal wastewater treatment plants permits technology transfer from one situation to another with a high degree of confidence. In the case of industrial wastewaters, inhibition frequently exists, calling for process design modification.

In the case of sludge handling and disposal, technology transfer must be very carefully applied, considering the nature and characteristics of sludges to be handled (municipal or industrial).

Priority pollutants is a new dimension that entered the water pollution control field over the past few years. In many cases conventional wastewater treatment technology is not able to remove these pollutants and innovative approaches are necessary. Technology transfer in this case is primarily drawn from experience in the chemical process industries.

Many of the technologies developed in the late 1960's and early 1970's were energy intensive. The trend today in the United States and many other nations, is to sacrifice some performance efficiency for economics due to increased energy costs and chemical and material costs. While Eckenfelder (U.S.A.) applauded this approach as being realistic in light of present economic conditions, he stated that consultants must exercise caution in the application of technology transfer with existing data. Many of the more recent technologies are specific for certain types of wastewaters, and the transfer of technology should involve a carefully planned and executed pilot plant or laboratory study. It is critical for the consultant to develop design parameters through appropriate pilot plants or laboratory studies and only employ technology transfer for similar wastewater characteristics.

Guarino (U.S.A.) complimented Eckenfelder for being one of the first and few scientists in the United States to promote the idea of "custom treatment": relying on laboratory and pilot-plant studies results instead of design parameters from textbooks.

Guarino (U.S.A.) stated most consulting engineers prefer to follow existing plant design and are reluctant to implement innovative technology. Usually the client must insist in order to implement innovative technology in his project. The U.S. Environmental Protection Agency (EPA) recognized the gap in technology transfer and implementation of innovative technology. Therefore, The U.S. EPA allocated special monies to fund projects involving innovative technology, but then "red-tape" restrictions made it very difficult to get grants for innovative technology.

Guarino (U.S.A.) mentioned we have not done much since the discovery of the activated sludge process in 1913 and that there is a lot more we can do. It was reported that 60% or more of the wastewater treatment plants in the United States built by public funding are not meeting permit requirements. Guarino (U.S.A.) said that we needed to have technology transfer so every engineer would know how to design a wastewater treatment plant.

Todo (Australia) commented from the floor that if one develops a successful innovative technology for a client, it is often that the client does not wish that this technology be transferred to his competitors and does not want to publish the results.

D. Paper D: "Involving Practitioners in Research - A Key to Successful Technology Transfer,"

by P. E. Odendaal (South Africa)

Odendaal (South Africa) defined technology transfer as the application of research findings, i.e., closing the gap between research and development. In the literature there is lack of common theory underlying the technology transfer process. This is an indication of the complex nature of technology transfer which is, in fact, not a single process but the end result of many processes which vary from case to case.

The author indicated the prerequisite for successful technology transfer is personal contact. Many of the standard techniques for technology transfer such as various forms of publications, conferences, seminars, films and demonstrations offer limited opportunities for personal contact and therefore mainly serve to create awareness of new knowledge, but generally much more is needed to induce the application of this new knowledge.

In the planning of a technology transfer program, provision should be made for creating as many opportunities as possible for establishing face-to-face communication between research workers and representatives of user agencies. The best way to do this would obviously be the involvement of potential users in the research process itself. Very few publications contain practical guidelines for effectively involving practitioners in research. Odendaal identified opportunities for practitioner involvement at various stages of the research process.

If technology transfer is equated to research application, the highest success rate occurs where a user agency conducts its own in-house research. In the real-world situation of water pollution research, in-house research by user agencies represents only a small portion of the total effort, with the bulk of the work being done through government funding. In technology transfer, actions originating with the research and research funding agencies are known as "push," while those arising with the user agency are known as "pull." The major effort to effect technolgoy transfer should be "push."

The first step toward the goal of research application should be a proper assessment of user needs well in advance of research planning. Approaches in assessing user needs include questionnaires, surveys, workshops and the establishment of special committees with user representation. User input is necessary in research planning and technology transfer must be built into a project during planning stages.

Close contact between user and researcher during the research and development process promotes technology transfer through a conditioning effect on both parties. The researcher gets a better grasp of the practiced problems and the user has a directive influence towards keeping the research user-oriented. There are various ways in which user agencies can be involved in the research process such as: direct participation in the research process, research funding by user agencies, steering committees and advisory panels and people transfer.

To increase the probability of application, research findings should be packaged in a format and language that is understandable and acceptable to the user. It is envisaged that most research agencies and research funding agencies will progressively recognize the importance of the vital role of user involvement in research for promoting technology transfer, and that user involvement will become standard practice in research programs which aim at user application.

Erlich (Namibia) commented that the less developed a country is, the smaller is the "pull" and the greater is the "push." In these countries there is ignorance or resistance to research. Engineers and scientists realize that they need a lot of "push" to overcome this resistance. Odendaal (South Africa) agreed without further comment.

E. Paper E: "Packaging of Information - Part and Parcel of Successful Technology Transfer," by M. J. Pieterse (South Africa)

Technology transfer in its broadest sense encompasses the collection, documentation, and dissemination of scientific and technical information, including data on the performance and cost of using the technology; the transformation of research and technology into processes, products and services that can be applied to public or private needs; and the secondary application of research or technology developed for a particular mission that fills the need in another environment.

Information transfer was defined as the act of informing or providing information about technological changes and advances through visual, audio and written media. The end result of technology transfer (or information dissemination) is to create awareness and stimulate interest in new technological developments. Technology transfer is the sum of those activities leading to the adaptation, adoption or demonstration of new technologies where the audio, visual and written media provide a partial vehicle for accomplishing the transfer.

For any technology transfer program, the necessary technology must be available or be made available by means of research and development. It is estimated that approximately 60% of the developed literature is unpublished material which is usually very difficult, if not impossible, to obtain. Only 40% of the total developed literature is visible, i.e., available for use. It is estimated that over 60 million pages of scientific and technical visible literature are distributed through 80,000 journals and 300,000 monographs annually. In a multi-disciplinary field like water, there is much information available and much more to come, all "begging" to be used.

Technology transfer may involve more than one organization as well as several key persons, e.g., the director of the research organization, the researcher and the technology transfer specialist. The technology transfer specialist should, to a certain extent, be a strategist who designs environments in which individuals are afforded opportunities to learn. The technology transfer specialist should be able to adopt new ideas, should be an opinion leader within the organization, be an excellent communicator and an expert on tailoring and packaging of information with a view to its application.

There is a need for research findings to be tailored and packaged in a format and language that is understandable and acceptable to the user. There are many packaging techniques which can be used to transfer new findings or to transfer recent research into a format which will be of practical use to designers, consultants and decision makers. Among them are mass media techniques (e.g., news release, television, radio), publications (e.g., newsletters, pamphlets, brochures and bulletins, trade journals and organizational scientific publications, capsule reports, state-of-the-art reports, manuals, handbooks and technical reports) and other techniques (e.g., films and video tapes, displays and exhibits, seminars, short courses, workshops and conferences, demonstrations, education and personal contact).

Hall (South Africa) commented from the floor that there is a gap between the practitioner and the researcher and that we need to close or eliminate this gap. Alexander (South Africa) commented that the researcher must read the literature if he wants to succeed, but the practitioner can often do his job adequately without referring to the published literature; therefore, the technology transfer specialist has to compete for the practitioner's time. According to Alexander (South Africa), the biggest gap in technology transfer is lack of comprehensive state-of-the-art reports.

F. Paper F: "Role of Equipment Suppliers," by J. Bernard (France)

Equipment represents one of the essential elements in the transfer of technology. The exchange of knowledge between researchers, designers, manufacturers and users is not equally easy in all cases, but in a free competition economy, the information is diffused very rapidly. Depending on the countries and the final owners and users of the equipment, the extent of technical knowledge and of the responsibilities demanded from equipment suppliers may be highly different, and this influences the efficiency and rapidity of technology transfer.

There is always a need for new equipment. This need may arise from: new regulations in terms of treatment levels, metropolitan development, economical evolution, better work conditions, reduction in personnel cost, improved reliability of the process, adaptation to large flow rates, and cost reduction.

Development of new equipment, which takes place in several stages, is more or less extended in time depending on the importance of the equipment and its novelty. Three major stages may be determined as follows: (1) small pilot unit; (2) industrial-scale prototype unit; and (3) first standard units. It is essential that equipment designed to convey or treat wastewaters and/or sludge be subjected to extensive full-scale tests under the environmental conditions they will meet, prior to being marketed.

A trustful cooperation between the manufacturer and the user is the key to a successful development work. The problems and defects which are met and the corresponding repairs and remedies must be recorded in all cases. It is essential that the manufacturer takes the operators opinion into account and conversely.

The equipment role in technology transfer takes three major aspects: (1) technical exchange between the user and the equipment manufacturer; (2) technical exchange between equipment manufacturer and process (or plant) designer; and (3) diffusion of technological information from one operator to another, from one designer to another, and sometimes from one manufacturer to another.

In environmental protection, information sources are immense. The number and frequency of events are among the highest in the various fields of industrial activity. Many reviews diffuse a large amount of direct advertising on the available equipment and easily draw the attention of the reader. In various (maybe too many) exhibitions, the general public may be shown new equipment and given much documentation. The rapidity with which the release of new original equipment is known in the world is a noteworthy fact. This is a remarkable sign of the importance of diffusion of technology transfer information.

Harley (South Africa) stressed the importance of feedback and stated that researchers and engineers do not get any feedback from operators about the success of their device. Eberle commented that this was indeed one of the major problems. The connection between researchers and users terminates at the end of a project and therefore researchers cannot learn about difficulties that may come about in later years.

Crook (Australia) stated that the burden of feedback should not be placed on the client. One of the duties of the researcher is to get the facts and follow up his research. He cannot sit in his ivory tower and expect everybody to feed him like a baby.

Mercer (South Africa) commented that we do not have enough experience in nutrient removal at the full-scale level. He asked the audience, when this information becomes available, to make this knowledge know.

IV. CRITIQUE OF SESSION

All the speakers made very good presentations. Each speaker presented a specific part of the theme "Technology Transfer." The presentations formed an excellent session of technology transfer and presented a current assessment of the situation of technology transfer with specific recommendations for improvement in the future. Issues and needs were effectively addressed by all the papers. In summary, the major significance of this session was to point toward the importance of technology transfer today and the need for improvement in the future.

There is wide international interest in all aspects of technology transfer. The participants agreed with all the speakers and their presentations. The lack of comments from the floor appeared to be mainly because the audience agreed with the speakers and did not have any further comments.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

All the papers presented in this session dealt with a subject matter which is of great importance in the United States. As such, all of the papers presented in this session will be valuable for Americans involved in technology transfer. All the speakers in this session complimented various United States agencies and organizations, especially the U. S. Environmental Protection Agency, American Water Works Association and the National Science Foundation, for their activities and achievements in the area of technology transfer. There is, however, a continuing need for improvement.

I. SESSION

A. Day: Friday, April 2, 1982
Hall: C
Time: 9:00 a.m. to 12:35 p.m.

B. Theme of Workshop: "Water Pollution Control in Developing Areas" (Theme 5)

Convenor: P. H. Jones (Canada)

Panelists: B. Hawerman (Sweden), K. Poppinghaus (Federal Republic of Germany), G. G. Cillie (South Africa), J. R. Simpson (United Kingdom)

II. REVIEWER

A. Name: Kazuyoshi Kawata

B. Position and Affiliation: Professor of Environmental Health Engineering and International Health
School of Hygiene and Public Health
The John Hopkins University
Baltimore, MD

III. DESCRIPTION OF WORKSHOP PAPERS

A. Paper A: "Review and Background," by P. H. Jones (Canada)

Jones (Canada) presented a general introduction to papers that followed. He made note that the topics being presented could be applied to developed, industrialized societies, but that they had peculiar meanings for developing countries. Several emphases were made. They included the important training aspects, infrastructure development, and the admonition that decision-makers from the village chief to the prime minister or president must be educated on the need for both water supply and sanitation and not just one utility at the expense of the other.

B. Paper B: "Legal and Administrative Aspects," by L. Brynolf and B. Hawerman (Sweden)

The authors noted the inadequacies in regulations and administration to deal with water pollution problems in many of the developing countries. They presented two case studies of "bad planning" that led to problems and offered features of legislation and administration, and procedures for dealing with pollution. It is not that countries do not have regulations. Too often, however, the regulations are unrealistic. They may simply forbid pollution or require the impossible, e.g., the discharge of water back into the stream at the same quality as it was withdrawn.

The two examples given were problems arising from (1) the combined wastewater from an abattoir, cannery, and tannery of the Botswana Meat Commission in Lobatse and (2) the sewerage system from Molepolole, a major village in the country. The Lobatse plant is a secondary plant with provision to treat 60 to 70% of the wastewater by tertiary treatment for reuse in the abattoir. Although designed by a reputable consultant, problems have arisen. They included (a) the repeated discharge of untreated or partly treated wastewater into the normally dry river bed; (b) no existing established effluent standards; (c) increase in nitrite and nitrate concentrations in groundwater in the area where the effluent is used for irrigation; (d) sulfide and sulfur problems in the biofilters due to the high concentrations of sulfate from the tanning process; and (e) sludge and solid wastes for which management had not been arranged initially. The problem at Molepolole involved the siting of the sewage oxidation ponds only approximately 300 m from wells of the village water supply without a thorough pre-assessment of the threat of pollution.

The authors suggested pollution control legislation with actions based on general consensus, administrative authorities to provide necessary expertise and enforcement, and procedures for handling matters as they arise in various situations. By the term "consensus," the authors were conscious of political implications, for in every development project, it is a rare occurrence for it to benefit all parties. It was indicated that water pollution control legislation should cover quantity and quality of all water resources and that the need for pre-assessment of each project is an essential part of legislation. Establishment of a Water Board, which will have the function of a "water court" to deal with water supply and water pollution problems and concerns was suggested as a part of water legislation. A Water Resources Department was also suggested to act as a policy-making and co-ordinating organization staffed by experts to advise the Water Board and be responsible for inspections.

Nebiker of the World Bank emphasized that the World Bank, although it is a lending institution, is also concerned with needs of countries. The concern of the World Bank is for the poorest countries, largely in West Africa, where there is an overwhelming need for water and where the cost for water is exceedingly high. It was evident that he would like to see more consideration given to appropriate technology. He stressed the need for water and wastewater services to move toward financial autonomy, i.e., self-financing through water fees and sewer service charges, without which maintenance programs cannot be set up realistically on a sound basis.

Lever (South Africa) called the attention of the session to the all important difference in the meaning of the words "practical" and "practicable." The sense of the presentation was "practicable," i.e., technically and economically feasible. Lever, taking South Africa as an example, commented that there is little industry-government cooperation and indicated that industries are not required to submit impact studies.

Best (South Africa) took issue with Level (South Africa) pointing out that there is increasing cooperation between industry and government in South Africa even in the absence of specific legislation. He suggested the need for the establishment of one authority for an integrated approach to pollution control.

Rivas-Mijares (Venezuela) also pointed to the importance of appropriate technology and stressed the need for adaptation not only to environmental conditions but also to socio-economic and cultural conditions. He supported the concept of technology transfer from the industrialized to the developing countries but with appropriate adaptation.

C. Paper C: "Training and Education," by K. Poppinghaus (Federal Republic of Germany)

The author's assignment was a difficult one since "training and further education in water pollution control in developing countries" covered an extremely wide scope and since situations vary from one developing area to another. The problem was compounded by his reference to "developing and threshold countries."

The need for hierarchically-structured training and for expertly-trained personnel was recognized. He noted the need to develop strategies, on a short-, medium- and long-term basis to deal with critical shortages of professionally trained personnel. The means to develop manpower which were suggested ranged from formal education at a university level to seminars, workshops, and on-the-job training. The shortcomings of technical education in developing countries was examined and proposed programs and assessments of training to address the needs in manpower development were presented. The contributions made by the Federal Republic of Germany in educational aid in developing countries were received. A plea for a more functional training of German professionals in developing country engineering applications was also made.

Van Rooyen (South Africa) suggested that the presentation pre-supposed that people in developing countries lived in formal townships and communities when, in fact, they live scattered, often on hill tops. He indicated that the training outlined was far too sophisticated and pointed out the need for appropriate training.

Barnard (South Africa) reported that in South Africa, there has been a recent development of classification of works according to size and complexity of operations and that training programs for operators have been established. He sought cooperation with other countries in the exchange of curricula and course materials.

Rivas-Mijares (Venezuela) recounted the good experience in Venezuela for training of operators in pilot plants employed also for research studies. He urged countries to take advantage of training opportunities available in centers sponsored by Regional Offices of WHO, such as CEPIS in Latin America.

Jones (Canada) pointed to language as one of the biggest difficulties in training, especially training of para-professionals. Kawata (U.S.A.) pointed to the importance of the understanding of socio-cultural factors and environmental health aspects by senior experts mentioned in the paper. Environmental methods for the control of tropical diseases must start with this knowledge.

Nebiker made reference to the series of studies on training conducted by national working parties for WHO, which he felt was a valuable reference for many countries. He also indicated that the training discussions at the 1981 AWWA Convention in Atlanta, Georgia deserved attention, as does the program developed in PAHO. Nebiker indicated that many of the current training programs have shortcomings and a fundamentally different approach to training is needed. Training must focus on the important aspect of transfer of technology. He also cautioned that often when training is done, there is no assurance that the trained will remain with the utilities. It is not, therefore, a one-time effort. He took issue with the justification of training developing-country personnel in Europe.

Williams (South Africa), speaking from experience of a project in Bophuthatswana, indicated that the personality of the educator/motivator is exceedingly important. A person may understand the language, but without the understanding of social customs, he may do more harm than good.

D. Paper D: "Low-Cost Technology," by G. G. Cillie (South Africa)

Cillie (South Africa) indicated that if low-cost technology is applied, costs can be reduced substantially and the goal of the Drinking Water Supply and Sanitation Decade will be possible. He provided descriptions of some typical water supply processes that may be used, including closed wells and slow sand filters. Where these simple systems are not possible in southern Africa, the National Institute for Water Research has developed a simplified standard design for water treatment, i.e., a rapid sand filtration plant with a post-disinfection step. For sanitation he discussed pit latrines, bucket system, and aqua privies as examples of rural areas where centralized treatment facilities are not normally warranted. For small communities with populations fewer than 5,000, the use of stabilization ponds was suggested; for larger populations, the South African experience with the "standardized" orbal treatment plant with only a mechanical process (i.e., a rotating disc) installed in the orban channels was suggested. Cillie concluded by stressing the need for training and the necessity in designs of systems to minimize the operation and maintenance costs. Without trained personnel, water and wastewater systems have little chance of continued functioning and with high cost of operation and maintenance, communities will not be able to afford the services.

E. Paper E: "Problems and Needs," by J. R. Simpson (United Kingdom)

Simpson (United Kingdom) discussed primarily the control of excreta-related diseases and the institutional and social developments that are required to effect the control Sanitary engineering and environmental health science have had historical roles in the prevention of diseases. For them to be able to assist communities, the lack of finances and education in health poses considerable problems. The need for competent personnel to design, construct, operate and maintain treatment works was stressed. These functions may not necessarily be done by the same personnel, but where possible, those hired to construct plants should be hired to operate and maintain them. He was cognizant of the acute shortage of trained personnel in developing countries and, at the same time, aware that general population must also be educated to use the facilities properly. An important point made in the training aspects was the desirability of the transfer of experience equally with transfer of technology.

The author presented the concept of planned phased improvement so that over periods of years communities can move toward greater coverage and increased services. The history of London, England and of Wales was recalled, as well as the phases in the development of water supply and wastewater utilities and their effects on morbidity and mortality.

Wolf (Federal Republic of Germany) remarked that low-cost technology is just as important in places such as rural Bavaria. He indicated that consulting engineers in his country are also reluctant to employ low-cost technology because there is insufficient fee to be obtained. Rogers (South Africa) speaking with experience in Tanzania echoed the problem by Wolf (Federal Republic of Germany). He impressed the session on the difficulty that even the Tanzanian engineer faced in seeking cultural information associated with a sanitation project and implied even greater difficulties for European engineers. He thought that youth-oriented service groups such as Peace Corps and Overseas Volunteers may have some success in reaching people.

Cillie (South Africa) commented that although most developing countries would like water piped to every home, this is not warranted. He advocated standpipes with spring-loaded taps to minimize wastage.

Herold (South Africa) raised the question, "Should you not learn from history?" He recommended planning early in metropolitan areas of developing countries for reticulation.

Simpson (United Kingdom) reminded the session that it was not too long ago even in the United Kingdom that some sanitary facilities were less than modern. He thought conceptual plans for water and wastewater systems should be drawn up by multi-disciplinary teams and ultimately implemented by engineers.

Bennett (Bophuthatswana) indicated that there was considerable progess being made in South Africa. He said that there is, however, a great need for middle technology personnel and invited such people to come to South Africa to help people in places like Bophuthatswana.

Mabale (Bophuthatswana) has had to deal with cholera in his area in recent time. He emphasized the importance not only of appropriate technology, but also of health education programs. The involvement of the people through organized village health committees in his region is showing good results.

Redshaw (South Africa) felt that there has been much too much attention paid to community systems when the people in Africa live largely in rural areas. Provisions of treatment works are often not practicable and reticulation often out of question. He thought more attention should be given to on-site systems.

Simpons (United Kingdom) agreed with the comment that water-carriage systems for waste disposal may not be the solution. He added that sewer systems are designed for a certain fixed life and that requirements for replacement costs are real. In the United Kingdom, much of the existing systems are deteriorating badly today and this is posing a great problem. Schemes in developing countries will be no different in years later.

Shelef (Israel) explained that 40% of the world population is deficient in protein intake. He advocated schemes for resource recovery and the production of income from products of community wastes, e.g., fish, algae, water for irrigation, and biogas for energy.

Williams (South Africa) favored the encouragement of commercial groups getting into the production of non-sophisticated equipment for water and wastewater treatment and reminded the session that diseases such as schistosomiasis can be transmitted by water contact and not simply by drinking.

Simpson (United Kingdom) commented that "appropriate technology" is as important in the United Kingdom as in developing countries. He felt that not enough effort is placed on educating people to use water supplies properly. In response to the comment on schistosomiasis he noted that in some irrigation schemes, improper design velocities have enhanced snail production and thereby the transmission of the disease.

Geevers (Bophuthatswana), a medical officer, spoke of the concern for water supply and sanitation, and undernutrition and their relation to health. He thought there should be rural planners, as much as there are town planners, who could place, say, the reticulation system for a community in context of economic viability as well as public health.

Lind (Sweden), the formal discusser, summarized the presentations. He noted that there is no sharp boundary between developing and developed countries. In fact, all societies continue to develop and societal development was compared to the growth curve of microorganisms. Looking to Sweden he showed that domestic water consumption has now leveled off to about 200 to 270 ℓ/capita·d. Industry is recycling its water more today, so that the net effect is a slight decline in water demand. The increase in water recycling has been brought about by the strict legislation increasing the price of water. This development has taken place over 80 years. He doubted very much that the developing countries could in a short period of time be able to satisfy most of the water demand in water-short areas to the level of Sweden. Economic means to finance facilities to meet the demand will be difficult to find.

Institution building was important and legal aspects, training at all levels, and planning were mentioned. A centralized authority staffed by engineers, biologists, microbiologists, and legal personnel was suggested and use of practical knowledge in mechanical and electrical fields, in training programs and training in-country was stressed. He indicated that sending people overseas for education had too many drawbacks, that designs of processes would be simple and that construction will use local materials as much as possible. Standardized plant designs discussed by Cillie (South Africa) made a great deal of sense, since standardization lends itself to easier training in operation and maintenance and makes for ease of supplying spare parts.

IV. CRITIQUE OF SESSION

The conference was advertised to include presentations, research papers and state-of-the-art deliberations on water pollution control in developing countries, especially since this is the International Drinking Water Supply and Sanitation Decade. Whether it was the question of venue or funding or whatever, many of the third-world countries were not represented. The state-of-the-art papers lacked fresh, original ideas to make the session one of vital interest. Furthermore, there were few papers in other sessions that dealt with problems of the less developed regions of the world. Although it was evident from a quick, visual survey that most United States and Japanese conferees were attending other sessions, nevertheless, the attendance in the state-of-the-art session was exceedingly good. There was an interest that seemed to express concern beyond the limited scope of the theme papers presented. Several of the participants from the floor were medical officers in South Africa.

There were some semantic problems among those present. The term "developing countries" was being interpreted loosely to represent whatever each speaker wanted it to mean and this was not helped by the use of the term "threshold countries." There was little said of the wide gap between rural and urban developments within a developing country. Therefore, what was advanced as appropriate technology was often challenged. Most engineers appeared to look at problems as consultants. They were concerned with processes, operation, maintenance, and economics. They were naturally involved more often with facilities for urban or semi-urban communities. Those in health departments saw environmental health problems in rural areas where diseases of the tropic were of concern. There the populations are often scattered with some living on hill tops. In such situations sophisticated schemes are too often totally inappropriate.

Training received considerable attention of all speakers but here again, there was a semantic problem. Poppinghaus (Federal Republic of Germany) mentioned "training and further education in natural sciences and engineering." He appeared to recognize the difference between training and education. Fortunately, many who attended the session interpreted training in the context of fitting the person to the job. There were expressions in favor of training to be more practical and to be arranged in-country at all levels of technical needs. Training of personnel in industrialized countries was seen by several discussers to be less desirable.

While the understanding of socio-cultural aspects and health education were mentioned, there was little substance in the discussions. This is probably understandable, since unfortunately environmental engineers and scientists rarely are in positions to contribute in these areas. The presentations also did not deal in any depth with health concerns in water supply and sanitation. The textbook presentation of excreta-related diseases was of encyclopedic value.

The engineer designing treatment units from the very simple to the more sophisticated systems to provide barriers to the transmission of diseases of the tropics must understand the diseases, vectors of the etiologic agents, and modes of transmission. He must also have an understanding of epidemiology to see through ecological fallacies. There was evidence that most engineers are ill-equipped to deal with environmental problems where such knowledge is necessary.

How much investment in water and wastewater schemes is required to improve health? This question was not brought up. Some may have gone away thinking that any amount will have an incremental improvement.

Resource recovery concepts were ably presented in discussions, but with time limitations not in any depth. An emphasis on this concept together with the aim of reducing, for example, diarrheal diseases would have been valuable to the participants.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The theme of the session focused on concerns in developing areas of the world. The emphasis in the presentations was largely in the direction of practice rather than in research. However, since United States government agencies and consulting firms are vitally involved today in projects in developing countries largely in aid programs, this area has interest. There are limited numbers of engineers knowledgeable in appropriate technology to design processes and schemes to protect populations from diseases of the tropics. There is also a wide gap in low-cost technology adapted to problems in water-short developing areas of the world. The common ground of tropical medicine and environmental engineering must be seen as an area where there are scientific inquiries that are needed to be made. Whether for altruistic reasons or for reasons of maintaining pre-eminence in tropical health, the scientific community in the United States should re-establish research programs in tropical environmental health. These involve the inactivation of etiologic agents in liquid and in solids fraction, processes for the removal of organisms, resource recovery built into treatment, and innovative economic management.

I. SESSION

A. Day: Friday, April 2, 1982
Hall: C
Time: 2:00 to 5:30 p.m.

B. Theme of Workshop: "Water Recycling" (Theme 6)

Convenor: K. D. Linstedt (U.S.A.)

Panelists: R. D. Heaton (U.S.A.), D.R. Albrecht (Federal Republic of Germany), C. F. Schutte (South Africa), H. I. Shuval (Israel), G. Eden (United Kingdom)

II. REVIEWER

A. Name: Richard D. Heaton

B. Position and Affiliation: President
Water Reuse Information Services, Inc.
10 Riviera Court
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III. DESCRIPTION OF WORKSHOP PAPERS

A. Paper A: "Review and Background," by K. D. Linstedt (U.S.A.)

Linstedt (U.S.A.) introduced the water recycling theme with appropriate definitions of reuse terminology for common understanding. These included: (1) Indirect reuse--reuse that occurs when waters used one or more times are discharged and withdrawn for subsequent use; (2) Direct use--planned and deliberate reuse of treated wastewaters for beneficial purposes. Potential reuse applications were described from groundwater recharge, agriculture, industry, recreation and aquaculture to domestic or potable reuse. Specific examples of wastewater reclamation and reuse were summarized at Phoenix, Arizona; Bethlehem Steel; Japan; Mexico and Israel.

Water reuse is truly a worldwide practice but individual communities must make the decision to conserve water by recycling based on the following considerations: (1) water quality; (2) health effects; (3) institutional restrictions; (4) costs; and (5) public opinion. With respect to public opinion, it was concluded that more public education is needed to insure successful reuse efforts.

B. Paper B: "Water Recycling Systems," by R. D. Heaton (U.S.A.)

The original intent of this invited paper was to present a general treatise on the initial treatment required for various reuses schemes via rivers, impoundments, lakes, groundwater or directly. Unit processes were to be detailed emphasizing performance and cost. Such a paper, to represent state-of-the-art conditions, would fill several volumes. Thus, the author limited his presentation to the reclamation and reuse of municipal wastewater and detailed cost functions for one United States installation.

Treatment was indicated to be a function of four variables that affected the decision of a community to recycle water. These were: (1) the intended use; (2) institutional considerations; (3) economics; and (4) health considerations and quality criteria. Beneficial uses of reclaimed wastewater were reviewed and a ten-step screening methodology was described to identify the potential market.

Institutional considerations was a general category to include a wide variety of factors influencing the reuse decision. The legitimate questions, and approximately 50 were posed, encompassed health, political, economic, cost and public issues. In general, a set of guidelines was developed for use in evaluating reuse potential.

With respect to health considerations and quality criteria, a beneficial use was listed along with the basis for establishing criteria. The prime water quality objective in any reuse situation is to prevent the spread of waterborne disease. The risk of human exposure is possible if inadequate safeguards are evident.

Of high importance in the written paper was the description of water recycling systems with respect to their costs and effectiveness in contaminant removal. Twenty-four treatment trains were proposed to meet intended reuse situations, ranging from irrigation to potable consumption.

To provide current cost data, detailed performance at the Water Factory 21, an advanced wastewater treatment plant operated by the Orange County Water District Southeast of Los Angeles, California was presented. The plant has operated successfully for five years, and maintains some of the best water quality and cost data available in the United States. In the formal proceedings, Heaton provided cost information on the facility for the October 1, 1979 to September 30, 1980 period. The purpose of the presentation in Cape Town was to update all data through September 30, 1981. This allowed close examination of inflation factors and provide the most current costs available.

Of significant importance it was noted that a 45% increase in costs had occurred over the one-year period of 1980-1981. With that jump in prices, it was indicated that AWT and several reuse situations seem doomed to economic failure. The plant was designed to treat 57,000 m^3/d through all of the unit processes and 19,000 m^3/d through the RO system. In 1951, only 19,000 m^3/d were treated with AWT and 15,000 m^3/d with RO. This was due, not to plant deficiencies, failures, or design problems, but to heavy winter rains that provided natural recharge, reducing the injection barrier demand that the plant normally provided. When the facility did not operate at design capacity, unit cost suffered as indicated in the period of 1980-1981.

To give a more accurate picture of current AWT costs, all cost data were adjusted to reflect full flow at a 90% plant factor. The results indicate a blended-water cost of 22¢/m^3. If the deep-well pumping and blending operation was deleted, the reclaimed water cost approached 33¢/m^3.

Data on less expensive reuse systems, emphasizing land treatment, agricultural reuse, and primary/secondary treatment, were presented.

Capital operation and maintenance costs (1981) for a 3800 m^3/d slow-rate land treatment system is estimated to be 29¢/m^3, including facultative ponds, 90 days of storage, surface flooding and 650 ha of land at $1230/ha. The cost of a new 3800-m^3/d AWT system to produce the same quality of effluent was estimated to be 75¢/m^3, or roughly 2.5 times the cost of the land system. However, even agricultural reuse costs were indicated to be site specific with costs ranging from 1¢/m^3 to 38¢/m^3.

It was concluded that costs are very site specific. Attention should be given to expected operational and maintenance costs prior to construction and the cost data provided should be for guideline purposes only.

Specific questions from the invited discusser, Chalmers, dealt with the status of reuse standards and criteria in the United States. These are practically none, except in a few states for sub-potable applications. Neither EPA or other regulatory agencies are anxious to develop and enforce water reclamation criteria, especially in potable reuse situations. With emphasis on recharge applications, the author indicated that many areas do not have the potential to apply the technology of aquifer treatment.

A legitimate point was raised that storing reclaimed water in aquifers does not solve monitoring problems. If a deleterious substance is discovered prior to distribution, a public health problem may be prevented but a useful aquifer is contaminated.

Other discussers challenged the need for water reuse at all, which was quickly dispelled with factual data on worldwide supply and demand relationships.

While chlorine was used as the principal disinfectant in most cost data, its use is not mandatory in the United States and other alternatives will suffice. The question was raised of why adjusted cost figures for Water Factory 21 were lower in 1981 than in 1980 with the response than design flows were low in 1980 as well. Had those data been adjusted in a similar manner, it would have given a more realistic impression of inflation over a one-year period.

Chalmers (United Kingdom) suggested that an early EPA statement was still true, i.e., renovated wastewater costs are prohibitive unless there is no other choice. This was refuted by Heaton (U.S.A.), using Denver as an example where other supply alternatives are available but more expensive than potable reuse.

C. Paper C: "Water Recycling--Industrial Applications," by D. R. Albrecht and K. Imhoff (Federal Republic of Germany)

The application of industrial water recyling techniques was presented by Albrecht (Federal Republic of Germany) with examples in various manufacturing plants such as: steel; pickling and plating, coal mining and coking; sulfite cellulose and paper production; sugar works; and power plants. Special emphasis was given to metal-finishing works and paper mills in Germany.

In 1975, the total industrial fresh water consumption was 29.9 x 10^6 m^3/d, in addition, 57.4 x 10^6 m^3/d of recycled water was used. A decrease in fresh water consumption was noted over the years while overall demands have increased. This lent credence to the importance of internal water recylcing in various wet industries.

Industry, depending on the product and proven procedures, can utilize either open- or closed-loop recycling schemes. Open-looped implied a cascading system where the same water was used successively in one or more operations prior to treatment. Closed-loop implied treatment immediately after use and recycled for that same use with make up as needed.

Some specific examples in the Federal Republic of Germany were:

(1) Steel Mills. The Salzgitter works in Northern Germany has a water demand for 25-30 m^3/s, but a fresh water surface supply of only 2 m^3/s. Optimizing internal recycling has met the demands

for cooling, waste transporting and process waters. In another steel mill, fresh water demands were reduced by reuse from 84 m^3/ton of steel produced to 4 m^3/ton.

(2) Pickling and Plating Works. Waste from these facilities are normally hazardous in nature and concentrated in geographical areas. In the Ruhr area alone, there are 607 metal-finishing plants. Water recylcing has become mandatory from both a resource and economic viewpoint. Multi-stage, counter-current and spray-rinsing techniques have reduced water consumption by as much as 99%. Ion exchange technology has become increasingly important for treatment and recycling.

(3) Coal Mining and Coking. The mining of a ton of coal requires 2.5-5 m^3 of water and coking an additional 5 m^3 with primary uses for washing and cooling. Eighty percent of the wastewaters are lost to evaporation but the remaining 20% must be reused to conserve valuable supplies.

(4) Sulfite Cellulose Plants. With a water demand of 500-900 m^3/ton of cellulose and strong wastewater production, these facilities become known as the greatest water polluters. Water demands have been reduced drastically through recycling techniques but one firm had to spend 22% of the total investment costs of wastewater treatment and air pollution control.

(5) Paper Mills. Sulfite cellulose is used for paper production and one German mill was able to reduce raw water consumption from 12 m^3/ton of millboard to 1.3 m^3/ton by applying recycling techniques and water conservation measures.

(6) Sugar Works. In sugar plants, water reuse has allowed consumption to reduce from 10-14 m^3/ton sugar beets to 1 m^3/ton. Wastewater is often stored during the process season and treated at a later date.

(7) Power Plants. Electrical consumption has doubled every 10 years since World War II. Once-through cooling is no longer possible and 1-2.5 m^3/s of fresh water are consumed for every 1000 MW produced. Multiple-cooling installations are 25% more expensive than single use.

The invited discusser, Baumann (U.S.A.) agreed that industrial water conservation has reduced consumption by as much as 70%. Conservation preceded reuse which could close the cycle and achieve zero discharge. The costs to reduce flows by 90% are 10% of those required to satisfy the remaining 10%. The last fractional increment is the most expensive. Most agreed with the sophistication of counter-current rinsing techniques but questioned the overall salt balance in some industries that generate 2 tons of salt for every ton of salt removed.

D. Paper D: "Water Recycling for Domestic and Agricultural Applications: State-of-the-Art," by C. F. Schutte (South Africa)

Agricultural reuse concepts are well documented and Schutte chose to emphasize the more controversial potable reuse situations. Indirect reuse, indirect recycling and direct recycling of treated wastewaters in domestic supplies were discussed with regard to engineering, public health and quality aspects.

There is very little difference between indirect and unplanned use of water containing effluents and planned recyling of reclaimed wastewater for potable purposes. The most important consideration in all reuse situations is that a polluted source is used for the production of drinking water.

Direct recycling has been taking place on an intermittent basis since 1969 at Windhoek, South West Africa. The 3800-m^3/d plant provides 20% of the water demand on a yearly average basis. But South Africa, with critical water supply problems, is looking at implementing potable reuse at other cities including Cape Town. Thus, the water supply regulator and research agencies keep a close watch on the issues of importance outlined below:

(1) Public Health Aspects. Safety of reclaimed water for human consumption is provided by existing standards for microbiological and some organic constituents. However, the question of what is safe for micro-organics is not so readily answered. "Safe" therefore must be qualified by a degree of risk for the particular situation. A relative approach of comparing reclaimed effluent quality with conventional supplies is not entirely satisfactory because it does not guarantee that either are safe. Schutte called for the establishment of an absolute reference quality and the development of drinking water criteria/standards regardless of source. Additional requirements such as treatment, monitoring frequency, and multiple barriers may be necessary to insure reuse safely.

(2) Epidemiological Evidence. It is difficult to identify subtle changes in a community's health pattern as well as to identify causal relationships or the effect of socio-economic forces. The two studies completed to date in Los Angeles and Windhoek indicate no meaningful relationship between consumption of reclaimed water and disease prevalence.

(3) Technology. It is an engineering assumption that any quality of water can be produced from wastewater if one is willing to pay the price. At extremely high costs, reclamation becomes infeasible. Realistic requirements must be set for unit processes and treatment trains without compromising quality.

(4) Public Attitudes. It would appear that public attitudes toward reclaimed water are not a significant obstacle in project development but adequate public information programs are necessary to insure success.

Current recycling projects comprising advanced reclamation technology are performing exceptionally well if judged by the quality of water that is being produced. Schutte expressed the hope that results from research on quality parameters, toxicology and epidemiology will become available in the near future to allay the apprehension still evident in parts of the scientific community towards potable reuse.

E. Paper E: "Health Risks Associated with Water Recycling,"
H. I. Shuval (Israel)

Shuval (Israel) began with the premise, "Before you take the risk, is there anything socially rewarding or beneficial from wastewater reclamation?" His reply was decided yes and he proceeded to defend that position.

While wastewater is 99.9% pure water, the remaining 0.1% of chemical and biological contaminants can result in serious health problems unless appropriate measures are taken. Indirect reuse again questioned where in times of severe drought, surface waters may contain 100% of recycled wastewater.

Conventional water treatment plants were said to be entirely inadequate to handle what may be a toxic waste. Criticisms were leveled against the water supply industry in the United States because of its hesitance to recognize covert reuse which is perhaps the most common and, in many ways, the most dangerous.

The question was posed - why should direct reuse be subjected to different standards and stricter requirements? Planned potable reuse programs must be submitted to municipal, local or national health authorities for review and/or approval. Under these circumstances, the initiators must accept full responsibility for any risks. In signing approval, health officials accept full responsibility both legally and morally that the project will not have negative effects. Thus, it is generally accepted that reuse situations will require more and extensive health regulations and standards.

Shuval (Israel) urged a pragmatic approach to potable reuse. That is, in water short areas sub-potable reuse schemes should take precedent, postponing for as long as possible the other decision until more information is available on epidemiological aspects. Shuval (Israel) quoted statements from the 1860's that human wastewater should be applied to the land for fertilizer value to nourish the world and prevent pollution of rivers or transmission of disease. There are social benefits to reuse from land application to potable use. In Israel, and to further satisfy the question of demand versus supply, the country is already using more water than they have, i.e., at the expense of mining precious groundwaters. In the future, the gap will have to be closed by reuse.

The author clarified his earlier statement of "I'd rather drink clean water than cleaned water." This referred to his hierarchial water use where, and if possible, the highest quality water should be used for drinking. Water reclamation plants and water plants in general should be considered places where the highest quality personnel and standards apply. The main message was an indictment of the water industry, as a whole, which has neglected the amount of wastewater in surface supplies and its hesitance to upgrade treatment from simple filtration and chlorination. He had complete faith in cleaned water when one knows what he is dealing with and plans accordingly. He was convinced that Windhoek water, with its rational design, was safer than drinking New Orleans water without recognized safeguards.

In response to a question on the value of epidemiological studies, *in lieu* of unknown chemicals being added daily to water supplies with 20-year latency periods before clinically diagnosed diseases are evident; Shuval (Israel) agreed that the research may be misleading because of synergistic effects.

A number of comments related to the fact that so much more needs to be known before we can endorse potable reuse. The author rebutted with the fact that public health was advanced before we had all the information especially with respect to viruses. He concluded with suggestions that water is the only food product that is manufactured, sold, and delivered before final testing. It should be much more expensive than it is to insure its safety.

Shelef (Israel) commented that some decisions are needed now; we cannot take all the time to assess risk. In his opinion, the 1963 U.S. Public Health Service drinking water standards were derived without empirical health data and constitute a greater risk than allowing potable reuse today. With respect to instrumentation, in his generation students could isolate 20 pure substances in the ppm range. In the 1970's better resolution resulted in ppb detection and in the 80's detection at the ppt level is achieved. Extrapolating this to the year 2000 would result in the ability to determine individual molecules of the 5 million known substances. In one glass of water, researchers could easily find one molecule of cobra venom or mustard gas. These results could be sensationalized unless a line is drawn somewhere. Proper use of public funds and realistic risk must enter the decision.

F. Paper F: "Water Recycling - Research Needs," by
A. L. Downing and G. Eden (United Kingdom)

Eden (United Kingdom) proposed that reuse of potable supplies is the most critical area for research with health effects being paramount. Since the duty of a water supply agency is to provide the public at all times with a wholesome water, a major objective of research is to reassure the public of its safety. A further objective is to carry out this mandated function economically and reliably. This might include consideration of reuse as a means of supplementing inadequate conventional sources.

Specific areas of research needs include: (1) Epidemiological Studies--while these efforts represent the ultimate test of reclaimed water, they must be coupled with tests capable of more rigorous control; (2) Animal Studies--these tests are limited because of extrapolation problems to humans, lifespans and inadequate sensitivities at nonlethal levels; (3) Bacterial/Cell Cultures--mutagenic screening tests are useful as primary indicators, but correlation of lab results with practice is difficult; (4) Biodegradability Tests--it is important to select one test from many that accurately predict the behavior of new compounds in the environment and not just in laboratories; (5) Chemical Analysis--non-volatile organics remain difficult to analyze with GC/MS techniques and the problem remains after identification and assessing harmful biological effects; (6) Microbiological Monitoring--Rapid methods of ascertaining microbiological safety are needed, especially with viruses; (7) Standards--standards must be based on the best available information, yet be realistic; (8) Treatment Processes--in specific areas, very sophisticated methodologies will be needed to meet stringent quality criteria; (9) Industrial Effluents--control of pollutants at their source is becoming increasingly important and mandatory in reuse situations; and (10) Administrative Control--realistic approaches to hazardous wastes are needed without over-reactions or shear neglect.

Eden (United Kingdom) closed his formal comments with inferences to needed changes in water/wastewater systems. Using water to dispose of human wastes was like using a 2000-ton train to remove 1 ton of rubbish and then throwing away the train at the end of the journey. With new thinking and additional research, on-site reclamation schemes may well prove to be practical approaches.

IV. CRITIQUE OF SESSION

Except for papers by Heaton (U.S.A.) and Shuval (Israel), the session was not representative of state-of-the-art conditions. The first author took time to offer current cost data and upgrade year-old proceedings. As expected, potable reuse generated the most enthusiasm and controversy. The current state-of-the-art is frankly that a lot remains unknown, but to sit idly and wait for all the answers is not practical. Risk must play a proper role in resource alternatives as well as economics.

The same questions appear to have arisen for the last five years. Why should potable reuse be treated any differently than indirect reuse situations currently being touted as safe? And the same answers come forth with a predominance of South African attitudes. Don't judge a water by its history but its present quality. Is it safe?

Industrial and sub-potable reuse is well founded with practical experiences worldwide. South Africa, with the only working potable reuse endeavor in nearby Southwest Africa, is interested in expanding the concept to other water-short areas. Criticisms outnumbered constructive comments and the country has had to establish its own proof. Sensitivities to world opinions are evident and South Africa's leadership in the field is a lonely position.

Because of a lack of promulgated reuse standards anywhere in the world, South Africa's multiple barrier effect is reasonable. Contrary to opinions expressed at Toronto in 1980 that potable reuse would never be allowed in the United States, it is a viable but very site-specific option that should not be ignored.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Interest remains high in wastewater reclamation and reuse, perhaps in a greater fashion overseas than in the United States. Water reuse activity in this country is very much a function of the weather and just as fickle. With the 1977-78 droughts in California came literally hundreds of legislative actions and funding proposals. But we forget quickly and when the rains came, interest subsided and apathy returned. Perhaps we respond better to crisis than proper planning beforehand.

I. SESSION

A. Day: March 29 to April 2, 1982
Hall: Civic Center

B. Theme of Poster Presentations: Water Quality Problems Caused by Toxic, Nuisance and Nutrient Chemicals

II. REVIEWER

A. Name: Clifford W. Randall

B. Position and Affiliation: Lunsford Professor of Civil Engineering
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

III. DESCRIPTION OF POSTER PRESENTATIONS

A. Poster Presentation S1: "Removal of Pesticides and Herbicides by Means of Adsorption on Activated Carbon," by D. V. Heroes (Belgium)

Granular activated carbon (GAC) was used to treat a wastewater containing chlorophenolics and phenoxycompounds, e.g., methylchlorophenoxy acetic acid, phenoxyacetic acid and phenoxypropionic acids. The study was conducted over a period of three years and one month using two GAC columns in series operated at an average flow rate of 14 m^3/h, with a contact time of 43 min in each column. A total of 123,000 m^3 was treated during the course of the investigation. GAC columns were shown to be effective way to remove chlorophenolics and phenoxycompounds from wastewater. Influent chlorophenol concentrations ranged from 0.8 to 6.4 mg/ℓ while effluent concentrations ranged from 2.6 to 16 μg/ℓ, for overall removal efficiencies ranging from 99.29 to 99.94%. Influent phenoxycompound concentrations ranged from 13 to 129 mg/ℓ with effluent concentrations of 57 to 484 μg/ℓ for removals efficiencies ranging from 99.60 to 99.93%. Organic carbon loadings on the activated carbon of approximately 20% could be obtained with average flow conditions.

B. Poster Presentation S3: "Adsorption and Biodegradation of Linear Alkylbenzene Sulfonates (LAS) by Activated Sludge," by K. Yoshimura and A. Nakae (Japan)

The authors indicated that adsorption of LAS homologues/isomers on activated sludge depended on the structure of the hydrophobic group of LAS. This tendency was consistent with that of their biodegradabilities. No accumulation of LAS and its biodegradation intermediates in activated sludge was observed. The degree of adsorption of commercial-grade LAS by activated sludge was a function of both the alkyl chain length and the location of the phenyl group on the chain. The longer the alkyl chain length and the shorter the distance of the phenyl group from the far end of the alkyl chain, the greater the adsorption of the LAS. The principal conclusion of these results was that adsorption of LAS by activated sludge depends on the hydrophobic properties of the molecule. The results further showed the the LAS was rapidly biodegraded and that the likelihood of biodegradation was also directly related to the hydrophobic properties of the LAS molecule. In summary, LAS molecules that are readily adsorbable are also readily biodegradable, and vice versa.

C. Poster Presentation S14: "Polyelectrolyte Toxicity Tests by Fish Avoidance Studies," by L. D. Spraggs, R. Gehr, and J. Hadjinicolaou (Canada)

A unique type of dynamic fish toxicity testing apparatus was developed. A continuous flow channel is divided by a partition for about one-half of its length. The chemical to be tested is injected on one side of the partition just downstream of its upstream end. Overhead video cameras and UV light are used to record the preferences of fish for the side with the injected chemical compared to the side without chemical. The cameras record the position of the fish every five minutes rather than operating continuously. The authors used 100 six-month-old *Salmo gairdneri* (rainbow trout) for each test at a temperature of 13-15°C. The chemical concentration that caused 50% avoidance was determined.

The apparatus was compared to three other types of toxicity tests: the static 96-h LC_{50} test for fish, the Microtox EC_{50} test, and 50% inhibition of algae (*Selanastrum capricornutum*). Rainbow trout were used for the static fish test. Two polyelectrolytes commonly used for water/wastewater treatment, and their monomers, were selected for testing. The monomers were polyacrylamide and dimethyldiallyl ammonium chloride, referred to as monomer A and B, respectively.

The conclusions were : (1) Polyelectrolytes are significantly more toxic than their constituent polymers; (2) Results for phosphorescent bacterial toxicity tests are inconsistent with those from fish and algae tests: (3) The dynamic fish test conducted over a relatively short period is at least as sensitive as the acute static fish test. It could actually yield information such as preference for substances actually known to be toxic from results of the static test; (4) From the magnitude of the concentration of polyelectrolytes showing significant toxicity, it appeared that discharges from waste treatment processes utilizing these polyelectrolytes could be hazardous to receiving water bodies.

C. Poster Presentation S15: "Mineralisation Problems in the PWV Complex--The Identification of Viable Solutions by Means of a Suite of Deterministic Models," by C. E. Herold (South Africa)

The Pretoria-Witwatersrand-Vereeniging (PWV) complex depends for its water supply on the River Vaal, which is also the sink for much of the pollution emanating from the region. With the onset of the rainy season, accumulated salts are washed off the catchment, causing unacceptably high TDS peaks in the primary water source. The salinity build-up is compounded by the feedback effect as effluents are recycled into supply. A suite of numerical models having meteorological data as basic input has been developed to simulate daily or monthly TDS concentrations at key points in the system for any specified conditions of demand or catchment development. Parameters relating TDS levels to economic costs are used to determine the benefits to be derived from adopting one or another of many different water resource management and pollution control strategies.

Among the findings to emerge were the following: (1) Within the PWV region the flow-weighted average increase in TDS concentrations during one usage cycle was 500 mg/ℓ; (2) More than half of the TDS load originating in the southern PWV region were derived from diffuse sources attributable to human activities; (3) The storage of salts in the soil moisture zone and their transport via interflow play a significant role in the routing of diffuse source mineral pollutants through a catchment; (4) A strong correlation ($r = 0.926$) was found between industrial water demand and the rate at which diffuse source salts were generated.

D. Poster Presentation S18: "Microbiology of Nutrient Removing Activated Sludge," by M. A. Hart and L. N. Malmed (South Africa)

The modified Bardenpho nutrient removal system was described. The build-up of microbiological life from plant start-up was recorded and *Acinetobacter* species was identified as a major component of the Gram-negative group of bacteria in a number of plants.

The daily development of microbial life in a Phoredox (modified Bardenpho) activated sludge system was monitored during start-up. Settled sewage was used as the only seed. The most important observations were as follows: (1) *Chironomid* worms appeared in large numbers during a temporary breakdown of the sludge removal equipment; (2) At the end of two months, *Acinetobacter* were present in scanty numbers and the experimental addition of primary clarifier sludge to the system greatly increased the *Acinetobacter* population and established their dominance; (3) Examination showed that the *Acinetobacter* cells contained phosphate deposits which diminished under anaerobic conditions and increased under aerobic conditions. Poly-β-hydroxybutyrate (PHB) granules in the same cells did the opposite; (4) Filamentous organisms such as *Nocardia* appeared to be able to accumulate polyphosphate.

The authors also surveyed the relative abundance of several species of bacteria in four nutrient-removing activated sludge plants and found that *Acinetobacter/Moraxella* species clearly dominated in each of them. Nutrient removal plants typically suffered from poorly settling sludges, particularly during winter.

E. Poster Presentation S25: "Interstitial Meiofauna as Indicators of Sandy Beach Pollution," by T. P. McClurg and J. D. Whitehorn (South Africa)

The authors proposed the assessment of the community structure of life forms adapted to the interstices between sand grains as indicators of the degree of pollution to which a sandy beach has been subjected and are performing the developmental research to make the approach feasible. To accomplish this, they are surveying the meiofauna of two beaches remote from major sources of pollution and that of some beaches at relatively polluted sites, all on the Natal, South African coast.

Results showed that the sand of beaches is, indeed, heavily populated. They found 36 organisms from 16 species in a typical 50 mℓ sample of sand. Nematodes were usually the major constituent and were generally found to be resistant to pollutants, whereas copepods were second in abundance and some were relatively sensitive to pollution. The nematode/copepod ratio was recommended as an indicator of beach pollution.

IV. CRITIQUE OF SESSION

In Poster Presentation S1, the author showed that efficiency varied with flow rate through the columns, yet very low effluent concentrations were obtained for all conditions used. Perhaps the most significant aspect was the demonstration that pesticide-herbicide concentrations of approximately 100 mg/ℓ can be reduced to effluent concentrations of approximately 0.060 mg/ℓ using GAC columns.

The procedures used by the authors of Poster Presentation S3 were very rigorous, sophisticated and thorough and can be accepted with confidence. It is doubtful that the results will be found transferable to other types of synthetic organics such as DDT and ABS, and the universal usefulness of the principles demonstrated herein for the screening of environmentally persistent organics is not likely. However, the results may provide an interesting insight into the mechanisms of the contact stabilization process of activated sludge. Perhaps the rapid adsorption of organics by activated sludge is more strongly related to their hydrophobic properties rather than to their colloidal nature. Results published in recent years have shown that a highly colloidal waste is not a sufficient condition for the contact stabilization phenomenon to occur.

The most interesting aspects of the results of Poster Presentation S14 were the very high toxicity of polyelectrolytes compared to the toxicity of the monomers used to build them, and the comparison of the dynamic test to the static fish test. It took 140 mg/ℓ and 900 mg/ℓ of monomers A and B, respectively, to kill 50% of the fish in the 96-h static test, but only 0.4 mg/ℓ and 0.2 mg/ℓ, respectively, of the polyelectrolytes made with those monomers. The difference was enormous and implied that polyelectrolyte use for wastewater treatment is potentially damaging to a receiving body of water. This aspect clearly deserves field investigation. The high toxicity of the polyelectrolytes was also indicated by the dynamic fish avoidance test and the 50% algae inhibition test. The concentrations for 50% fish avoidance, however, were twice the concentrations of the LC_{50}, indicating that fish may unknowningly remain in the presence of fatal concentrations of polluting chemical. By contrast, the fish avoided concentrations of monomer that were only a very small fraction of the LC_{50} concentrations.

The failure of the Microtox test to indicate toxicity for chemical concentrations that were even remotely close to toxic levels indicated by the other three tests casts serious doubt on the usefulness of this approach. For polyelectrolyte C, it erred by a factor of 37,500X, compared to the LC_{50} concentration. The smallest error factor was 96X compared to LC_{50} concentrations.

In conclusion, though, it did not appear that the authors demonstrated that the dynamic test was superior to the acute static test. For the low toxicity monomers, the avoidance levels were much less than the LC_{50} concentrations whereas for the highly toxic polyelectrolytes the avoidance levels were greater than the LC_{50} concentrations. Considering the high equipment cost of the dynamic test equipment, it is doubtful its use could be justified. Interestingly, the 50% algae inhibition test most closely approximated the LC_{50} results.

In Poster Presentation S15, Herold (South Africa) adapted a group of specific models into a relatively comprehensive approach that can be used to simulate the complicated interdependence of water resources, water demands and water pollution in a complex, industrial watershed. The problem evaluated was the buildup of total dissolved solids (TDS), but it seems highly probable the models could be used to project the buildup of a variety of diffuse source pollutants in a watershed where partial recycle is occurring. The approach appeared to be particularly valuable for the evaluation of proposed basin-wide management and planning options and parameters relating TDS levels to economic costs are included to facilitate such evaluations. The developmental work that has been performed by the author is impressive.

In addition to the IAWPR poster presentation, the author will present a related paper at an IAHS conference at Exeter, England in July, 1982. Preprints of that paper can be obtained from the author as can copies of the computer program documentation. His address is: Dr. C. E. Herold; c/o Stewart, Sviridov & Oliver; P. O. Box 61672; Marshalltown; Johannesburg, 2107 South Africa.

Poster Presentation S18 was a companion to Poster Presentation S17, and both are outgrowths of the wastewater treatment research effort that has consumed the attention and energies of many of the South African workers during the past eight to ten years, i.e., the excess biological removal of phosphorus by activated sludge. The significance of this paper cannot be truly appreciated outside of the context of the overall efforts, which were thoroughly documented and discussed at a post-conference symposium held in Pretoria. The reader is referred to those proceedings which can be obtained from: The Secretary, Post Conference Seminar on Phosphate Removal in Biological Treatment Processes, c/o Water Research Commission, P. O. Box 824, Pretoria 0001, Republic of South Africa, or IAWPRC Headquarters.

About 30 full-scale Bardenpho or Phoredox nutrient-removal activated sludge plants have been constructed and operated throughout South Africa. A recent survey, however, showed that very few of these plants were actually achieving nutrient removal to the level for which they were designed. In the meantime, research at the University of Cape Town established that totally anaerobic conditions must precede the aerobic portion of the treatment system for excess phosphorus removal to occur and this combination was not typically accomplished by the Bardenpho-Phoredox systems because of recycle patterns. Three of the plants were subsequently modified in accordance with the research findings, and excellent phosphorus removal is now being attained at these facilities. The Cape Town University researchers also identified a bacterial genus with very unusual abilities as the primary phosphorus removing organism. This genus was *Acinetobacter* and the researchers claimed that anaerobic conditions preceding the aerobic section give these bacteria a competitive advantage over other activated sludge bacteria. Poster Presentation S18 was the result of research designed to check the validity of the Cape Town University findings as was Poster Presentation S17.

The original thrust of the work was the description of microbial life as it developed during plant start-up. Nothing unusual or not already known was revealed by this portion of the work. The appearance and subsequent development of *Acinetobacter* as the dominant bacteria was very significant, however, as was the demonstration that it was the dominant bacteria at four separate wastewater treatment plants achieving excess phosphorus removal. Further indications are that the techniques used actually underestimated the numbers of *Acinetobacter* present. These results, combined with the results of the Cape Town University researchers and the demonstration of phosphorus granules in *Acinetobacter* (Poster Presentation S17), seems to rather conclusively establish *Acinetobacter* as the primary microbial agent responsible for excess phosphorus removal. It should not be ignored, however, that other organisms such as *Nocardia* have also been shown to store phosphorus. Unfortunately, *Nocardia* and its companions frequently exist in filamentous form and cause poor settling of the activated sludges in phosphorus removal plants. The respective growth requirements of *Acinetobacter* and *Nocardia* need to be carefully studied and compared to see if operational methods that would encourage *Acinetobacter* while discouraging *Nocardia* can be devised. Filamentous growths resulting in poorly settling sludge appears to be the principal problem remaining in the development of activated sludge plants that can remove phosphorus concentrations typically found in domestic sewage down to concentrations of 1.0 mg/ℓ or less.

The overall merit of Poster Presentation S25 would seem to be as sound as any diversity index approach. Better definition of the extent of nematodes resistance to pollution and the extent of copepod sensitivity to pollution is needed for more complete evaluation.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The mechanisms of the contact stabilization activated sludge process have never been well understood. This has hampered the development of design formula and has made the use of laboratory/pilot plant testing essential for determining its usefulness for specific wastewaters. The results of Yoshimura and Nakae (Poster Presentation S3) that adsorption on activated sludge was primarily related to the hydrophobic properties of the organic chemical may be the key towards a better understanding, and eventually better design technique, for this biological process.

The high toxicity of polyelectrolytes for aquatic life indicated that considerable research needs to be performed to determine the implications of this for the utilization of polyelectrolytes in water and wastewater treatment plants. For example, when polyelectrolytes are used to enhance activated sludge settling, what concentrations escape in the effluent? Can harm to aquatic life be demonstrated in the streams? The widespread use of polyelectrolytes in the United States seemingly indicates that a high priority should be placed on this type of research.

Research of Spraggs et al. (Canada) (Poster Presentation S14) casts extreme doubt on the usefulness of the Microtox method. This approach did properly rank the relative toxicity of the chemicals but it showed a grave lack of sensitivity. From their results, it would appear to have very limited usefulness.

The models developed by Herold (South Africa) (Poster Presentation S15) should have considerable application in the United States. They should be directly applicable to western states where considerable irrigation is used and the build-up of TDS is a problem. They should be of even greater interest to those concerned with predicting/controlling pollution from diffuse sources. With relatively small modifications, it should be possible to adapt the models for pollutants other than TDS, such as nitrogen, phosphorus, and heavy metals, all of which are of considerable concern in numerous urban areas throughout the country.

The work pertaining to excess biological phosphorus removal (Poster Presentation S18) is of great interest in the United States in the immediate future and should have far-reaching effects. The demonstration in South Africa that phosphorus can be removed to very low levels by biological methods, without chemical addition, and that the process can be reliably controlled, should stimulate interest in such an approach in this country. In fact, it has already occurred to a significant degree. The establishment of *Acinetobacter* as the primary biological agent responsible for the phenomenon should stimulate considerable research towards developing an understanding of the limitations and capabilities of the organism, which will provide insights in how to control its performance during plant operation. Further, the implication of *Nocardia* as a cause of poor settling of nutrient removal sludges should restimulate research interest in an organism that has caused serious foaming problems in treatment plants all across the country.

I. SESSION

A. Day: March 29 to April 2, 1982
Hall: Civic Center

B. Theme of Poster Presentations: Effects of Pollutants on Receiving Waters

II. REVIEWER

A. Name: Herbert C. Preul

B. Position and Affiliation: Professor of Civil and
Environmental Engineering
University of Cincinnati
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III. DESCRIPTION OF POSTER PRESENTATIONS

A. Poster Presentation S16: "A Chemical Investigation of a Marine Sewage Outfall," by P. D. Bartlett and G. A. Eagle (South Africa)

Table Bay, situated in the northern end of the Cape peninsula near the southwestern tip of Africa, is bounded on the south and east by the City of Cape Town and on the north and west by the Atlantic Ocean. The seabed is mostly rocky with occasional patches of sediment. The largest sediment accumulations occur close inshore in the south and southeast. The bottom topography is gentle and reaches a maximum depth of 35 m on the western side between Robben Island and Green Point.

The bay receives waste from a number of inputs, notably the Green Point sewage outfall. Approximately $3 \times 10^4 m^3$ of raw sewage are discharged daily via this outfall. The pipeline is about 600 m long and has a single port at a depth of about 17 m. The other major waste inputs include the Table Bay harbour area and the Salt River which carry partly treated and other industrial effluents. This study is being undertaken primarily to determine the behavior of sewage from a single outfall (Green Point) on entering the sea. The contribution of this effluent to the overall chemical budget of Table Bay, including nutrients and trace metals, is being examined. Studies of water chemistry, sediment chemistry and biology, have been undertaken to complement physical oceanographic studies carried out previously.

Forty-five sampling stations were set up in the bay. Contour maps have been prepared with a computer package to display the distribution of the various chemical parameters. Typical residence time of water in the bay is two-three days. The contour maps showed clear plumes for many of the measured parameters extending from the outfall. The shape of the plume depended on the wind regime at the time of sampling. After calm weather, higher concentrations were found close to the shore, while after a south-easterly wind, the plumes extended from the outall towards the middle of the bay. The areas of high nutrient and trace metal concentrations corresponded with the areas of depleted dissolved oxygen. Degradation of the sewage thus leads to lower oxygen levels in the water. The source of these species could be either upwelling or a bottom current flowing in the opposite direction from that indicating a likely atmospheric input.

The highest concentrations of all the trace metals studied in the sediments were in the Granger Bay-harbor entrance area. These high levels did not correlate well with particle size or organic content and it is not yet clear whether these metals originate from the sewage.

Estimates have been made to assess the mass of nutrients being carried into and out of the bay. In all cases, there was a net removal of nutrients from the water within the bay. In view of the vast amounts of nutrients introduced into the bay through the upwelling process, it is likely that the contribution from the sewage outfall will be relatively insignificant.

A similar calculation concerning transport of metals into and out of the bay has been performed. Allowing for the wide margin of error in such calculations, there was excess iron and lead leaving the bay whereas more zinc was being introduced than lost.

These results represent the first part of a long-term study to assess the impact of sewage and other effluents on an area such as Table Bay. In particular, budget calculations will be attempted to try and ascertain the long-term effects, if any, of sewage disposal in coastal areas.

B. Poster Presentation S19: "Nutrient-Salinity Relationships in Four Estuaries of the Cape Province, South Africa," by G. A. Eagle and P. D. Bartlett (South Africa)

In order to predict the behavior of pollutants in estuaries, it is essential that the chemistry of unpolluted estuaries be better understood. For this reason, four estuaries in the Cape Province have been studied, with the aim of understanding the concentration gradients which occur for various chemical species in the transition from freshwater to seawater.

The estuaries studied were the Orange, Olifants, Berg, and Breede. All are relatively unpolluted except for agricultural runoff. The mouth of the Berg River has been modified by the construction of breakwaters, but the other estuary mouths are still in their natural states.

The general behavior of nutrients in estuaries has been established in a number of studies and results have been summarized. However, to date, no similar work has been done in South African estuaries. This poster described the work carried out and includes some results which are significantly different from normally expected concentration gradients including the following: (1) Salinity. The degree of penetration of saltwater into the estuaries was found to be far more dependent on river flow than on tides. It appeared that the mixing of salt- and freshwater can take place anywhere in the lower, approximately 25 km of these estuaries, depending primarily on river flow, but to a lesser extent on tides; (2) Nitrate. The distribution and levels of dissolved nitrate indicated two major nitrate sources were land runoff and upwelled marine water. The relative importance of each process depended on local conditions and season. (3) Phosphate. Phosphate concentrations in estuaries normally remain more or less constant due to some form of buffering mechanism; this was found in most cases in this study. (4) Silicate. In most cases, the expected inverse linear relationship between silicate concentration and salinity was observed. (5) Dissolved oxygen. The dissolved oxygen concentrations in all the rivers were close to the theoretical saturation levels.

As an overall conclusion, the four rivers all showed distinct differences from each other and there were also some differences from the normally expected behavior of nutrients in estuaries. These differences are being investigated further.

C. Poster Presentation S20: "The Role of DOC and TOH Measurements in Water Pollution," by R. A. Van Steenderen (South Africa)

The beneficial effects of water chlorination as a means of safeguarding potable water supplies against bacterial and viral contamination are still virtually unsurpassable. However, relatively recent findings have established that chlorination of most surface waters gives rise to the formation of undesirable halogenated organic compounds, of which chloroform is the most predominant.

A highly successful unit process which has become an integral part of water purification is that of active carbon adsorption which serves as a final polishing step to remove color and odors but which also reduces the amount of organic compounds, including halogenated organic precursors, in the final water.

The organic capacity of active carbon is, however, not unlimited and periodic assessments are required to determine its condition and effective life span. Besides the standard and lengthy quality parameters used to determine the life expectancy of the carbon itself, an alternative and less complicated method is that of monitoring the quality of the outflow of the carbon column in terms of parameters such as dissolved organic carbon (DOC) and total organo-halogens (TOH). The tremendous progress in development of analytical methods for these parameters has resulted in more efficient group detection techniques, lower detection limits and increased analysis rates.

Pilot plant studies whereby activated sludge plant effluent was passed through columns containing Filtrasorb 300 active carbon illustrated that regular DOC measurements could serve as early indications of carbon column 'breakthrough.' Ultraviolet absorbance (4-cm path length at 275 nm) measurements were used to indicate a deterioration in carbon conditions, and because of their simplicity, were suitable as a confirmative test.

A twelve-month survey of Pretoria drinking water found further application of DOC, TOH and UV absorption measurements including a relatively new concept called the total organo-halogen potential (TOH_p) value, whereby samples were overchlorinated to 100 mg/ℓ in the laboratory and left for 48 hours before analysis. Statistical evaluations showed that with the exception of TOH, positive intercorrelations existed between DOC, TOH_p, and UV absorption measurements for a specific water. The significance of these correlations was dependent on water quality consistency and the correlation between DOC and UV absorbance was seasonably dependent.

D. Poster Presentation S24: "The Impact of of Diffuse Atmospheric Nutrient Loading on an Oligotrophic Freshwater Lake in a Developing Urban and Industrial Area (Richards Bay, South Africa)," by C. G. S. Archibald and M. S. Muller (South Africa)

Significant increases in urbanization and industrialization occurred from 1964 to 1981 in the catchment and Richards Bay area.

Atmospheric fallout of total nitrogen increased over this period. Increases in algal growths in the spring and summer have caused water treatment problems with commensurate increases in costs. Corrective steps taken in the treatment plant included the addition of dissolved air flotation and improved filtration procedures.

E. Poster Presentation S30: "The Measurement of Organic Pollution of the Sea Using Satellite Imagery," by L. V. Shannon, N. M. Walters, and A. G. S. Moldan (South Africa)

During the austral summer of 1978-79 and 1979-80, a series of ocean color experiments were undertaken in the southern Benquela current region off South Africa. The objective of the experiments was to relate the Coastal Zone Color Scanner radiance measurements from the NIMBUS-7 satellite to chlorophyll (phytoplankton) distribution, to organic pollution emanating from the fish processing factories in the St. Helena Bay area and to the dynamics of the fronts associated with the upwelling system. The Coastal Zone Color Scanner (CZCS) is a six-channel scanning radiometer with four channels in the visible 443, 520, 550 and 670 nm, one in the near infra-red at 750 nm and one in the infra-red at 11.5 μm.

Extensive and intensive ground truth observations were made to validate the results obtained from satellite imagery and a good correlation was found between the chlorophyll concentrations deduced from the latter and direct measurements *in situ*.

The concept of using satellite imagery is not new. The main problem with satellite observations is that, unless there are good ground truth data to support these measurements, the interpretation must remain suspect.

IV. CRITIQUE OF SESSION

The poster presentations were concentrated on the effects of chemical and organic pollution due to wastewaters. Particular study and emphasis was given to the effects of nutrients such as various forms of nitrogen and phosphate. New techniques and approaches in monitoring have been demonstrated, e.g., satellite imagery of organic pollution in outfall waters.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The reported results in this session are seen as being pertinent to United States needs in the form of approaches for monitoring water quality. Several of the nutrient studies extended over a number of years of study (e.g., Poster Presentation S24), and the results certainly can provide important insights where developing urban and industrial areas are affecting bodies of water which are important water supplies.

I. SESSION

A. Day: March 29 to April 2, 1982
Hall: Civic Center

B. Theme of Poster Presentations: Oil Spills and Environmental Pollution

II. REVIEWER

A. Name: Thomas H. Goodgame

B. Position and Affiliation: Director, Corporate
Environmental Control
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III. DESCRIPTION OF POSTER PRESENTATIONS

A. Poster Presentation S7: "Total Mercury Concentrations in Some Species of South African Commercial Marine Fish," by J. Henry (South Africa)

Results of the analysis for mercury for sixteen species of fish, native to the South African coastal waters, and primarily from the western or South Atlantic, coast were presented. The range of mercury concentrations was from less tha 0.03 to 0.36 μg/g with the lower limit of the analytical technique being 0.03 μg/g and the mean for all of the determinations being 0.11 μg/g. Data for a world mean for fish species was indicated to be about 0.13 μg/g. On this basis, it was concluded that fish mercury concentrations were similar to concentrations reported in other areas, and were therefore "natural."

B. Poster Presentation S8: "Toxicity Testing of Oil Spill Dispersants," by A. Moldan and P. Chapman (South Africa)

A bioassay test used to screen oil dispersing agents for use in a marine environment was described. Using crude oil as a control, the percentage of subjects that die with the dispersant added to the crude oil/water system are compared. Under normal conditions, 40% of the test specimens would die. If the percentage that die with the oil dispersant added to the system does not exceed 50%, the dispersing agent is passed for use. Usually there were significantly more survivors after oil treated with dispersant versus no dispersant. A number of commercial oil dispersing agents have already been screened and passed for use.

C. Poster Presentation S9: "Effects of Oil on Reproductive Capacity of *Callianassa kraussi*," by L. F. Jackson (South Africa)

Eggs were exposed to oil in water at concentrations ranging from 0 to 45 ppm for either the last two weeks before hatching or for the full incubation period, which was of the order of four to five weeks. The results are reported as the percentage of the test specimens that hatch and the percentage successful larval development. The percentage hatch and percentage of successful larval development decreased with increasing oil concentration and with length of exposure. The low levels of successful development were interpreted to indicate many deformities before hatching. The poster was well illustrated with photographs of typical deformities that would be expected under the conditions of the experimental study.

D. Poster Presentation S10: "The Use of Ultraviolet Absorption in the Measurement of Fish Factory Pollution," by P. Chapman (South Africa)

The area studied was a bay with a number of fish factories. It was a tidal bay in which a number of problems developed. Fish factories operate from December through May and they created high oxygen demands and high phosphate concentrations in the waters to which they were discharged. Fish oil slicks frequently formed scales discharged with the other materials accumulated on the bottom. Ultraviolet absorption at 230 nm and integrated absorption over the range of 250 to 350 nm are used to determine DOC and oxygen depletion. This paper describes the analytical technique only.

E. Poster Presentation S28: "Some Aspects of the Sensitivity of Juvenile *Jasus lalandii* to the Water Soluble Fraction of Crude Oil," by J. R. Lipschits (South Africa)

This poster reports the first phases of a study of the effect of the water soluble fraction (WSF) of crude oil on juvenile *Jasus lalandii*, commonly called the South African lobster, rock lobster or crayfish. It was reported that the heart rate increased with exposure to water that had been permitted to dissolve the WSF form crude oil.

F. Poster Presentation S29: "Ecotoxicological Evaluation of an Oil Gelling Agent--Its Effects on Photosynthesis of Seaweed," by T. Yoshida, T. Maruyama and H. Kojima (Japan)

This was reported as a new oil treatment system. The gelling agent was *n*-lauryl-glutamic acid-dibutyl amide. The gelling agent was reported to do a good job of producing a solid gel, but it appeared to add dissolved organic carbon to the sea water.

IV. CRITIQUE OF SESSION

Poster Presentation S7 dealt with mercury content of commercial marine fish in South African waters. This paper was of very limited interest.

Poster Presentations S8 and S29 dealt with methods for cleaning up or dispersing oil spills. These were both well prepared posters. The explanations were clear and useful to one interested in the field.

Poster Presentations S9 and S28 dealt with aspects of the effects of crude oil (petroleum) on marine life. Both these posters form a portion of the Ph.D. theses of the authors. The authors were frequently in attendance and were very willing and capable in answering questions and responding to comments.

Poster Presentation 10 dealt with the use of ultraviolet absorption for analysis of wastewater from fish factories and was highly specialized dealing with the analytical techniques only.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Significant methods of controlling oil spills evaluating oil spill clean-up agents were presented. There is a continuing need in this area and the methods given in Poster Presentation S8 are already in use in South Africa. While the test results appeared to be crude, they did give useful and usable results. Poster Presentations S7, S9 and S28 were particular to species of South African waters and may be generally applicable elsewhere. The information developed in Poster Presentation S7 will generally add to the data base for mercury levels throughout the world. The methodology presented in Poster Presentation S10 was specific to a particular location. However, the method of ultraviolet absorption might usefully be transferred to locations that might be of more interest in our fisheries industry and in waters receiving wastes from meat and fowl processing locations.

I. SESSION

A. Day: March 29 to April 2, 1982
Hall: Civic Center

B. Theme of Poster Presentations: Wastewater Treatment

II. REVIEWER

A. Name: Robert A. Canham

B. Position and Affiliation: Executive Director
Water Pollution Control
Federation
Washington, D.C.

III. DESCRIPTION OF POSTER PRESENTATIONS

A. Poster Presentation S2: "Computer Control in a Sewage Plant, Methods and Experience," by C. P. Kuznia (Federal Republic of Germany)

This was a concise and well-presented pictorial and graphical display of an integrated computer application for operational control of a small treatment plant in Germany. The computer system had a voice component which appeared to be the only unique feature. It would not be expected that there would be any particular difficulty in applying the same principles to treatment plant control in the United States or elsewhere. No information was available on how long it took to develop the software, at what cost the system was installed and operated, nor what functional problems have been experienced.

B. Poster Presentation S17: "The Location and Nature of Accumulated Phosphorous in Activated Sludge," by L. Buchan (South Africa)

This laboratory study made some positive statements but also left some questions. The author confirmed the importance of *Acinetobacter* species in the phosphorus removal process in activated sludge. The work also concluded that the nature of the carbon source in the substrate has a profound influence on the amount of phosphorus accumulated. The author did not draw a conclusion relative to whether the role of the anaerobic zone in a nutrient removing activated sludge plant is to subject bacteria to stress or to provide phosphate accumulators with the necessary substrate to ensure their continued growth.

C. Poster Presentation S23: "Influence of Sewage Irrigation on the Groundwater Quality," by G. Milde, H. Dizer, Z. Filip, V. Newmayer, and V. Paibyl

This poster presented in tabular and graphical form a series of groundwater data that the authors claimed supported their conclusion that there has been no significant degradation of groundwater quality during the 80-year history of applying sewage to land. There was no evidence of innovative work in the report.

D. Poster Presentation S32: "Precipitation of Calcium Phosphate and pH-Effects in Denitrifying Biofilms," by E. Arvin and G. H. Kristensen (Denmark)

An excellent summary brochure accompanied this poster. This type brochure would be a good sample to use as guidance for those preparing posters. In less than five minutes, a viewer of the poster and reader of the brochure can tell what the work was, the basic premises, methods, results, and conclusions. For those with special interests in phosphorus removal, further discussion with the authors is encouraged. There was no evidence that this laboratory work has been extended to either pilot- or full-scale work.

E. Poster Presentation S33: "Biochemical Changes Associated with Luxury Phosphate Uptake in a Modified Phoredox Activated Sludge System," by D. J. J. Potgieter and B. W. Evans (South Africa)

This poster related to work done on a commercial process for phosphorus removal. The process appears to be similar to the patented Phostrip Process in the United States. The poster described a bench-scale project and the state observations from the work were as follows: (1) increased amino acid content occurred during good P-removal, and (2) concurrent release of P, Mg++, and Ca++ occurred. The authors did not relate the observations to application and the circumstances that caused "good" P-removal were not discussed.

F. Poster Presentation S34: "L.F.B. - Full Scale Operation," by D. S. Render (South Africa)

This describes an apparent commercial process that incorporates the full range of physical, chemical and biological unit processes used in advanced waste treatment. For example, chemical (organic) flocculation, other flocculants, multimedia filtration, and carbon filtration were included. The application has been in treating complex industrial wastes. Extremely high degrees of removal of organic and heavy metals were shown in the tabular form but the composition of the raw wastes was not specified. The processes used were those of accepted technology.

IV. CRITIQUE OF SESSION

Poster presentations are generally hampered in their effectiveness by the limited space available for presentation and by the nonavailability of the authors during the posted times. Summary brochures to accompany the posters would be very helpful in providing additional information.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Research activities in South Africa have begun to elucidate the mechanisms involved in luxury phosphorus uptake. With this understanding, they have begun to develop and apply this technology on a full-scale basis which optimizes this process. Closer examination of this work by United States engineers and equipment vendors is suggested.

I. SESSION

A. Day: March 29 to April 2, 1982
Hall: Civic Center

B. Theme of Poster Presentations: Wastewater Treatment

II. REVIEWER

A. Name: K. Daniel Linstedt

B. Position and Affiliation: Project Manager
Black and Veatch Consulting
Engineers

III. DESCRIPTION OF POSTER PRESENTATIONS

A. Poster Presentation S35: "Suppression of Density Waves in Clarifiers," by M. C. Murphy, R. R. Hudgins, and P. L. Silverston (Canada)

Experiments on 1.2-m diameter model clarifier operating at overflow rates and suspension concentrations corresponding to municipal treatment practice showed that baffles, designed to function as wave traps, suppressed low-frequency, large-amplitude density waves observed in these units. Simultaneous measurements of solids removal show substantial improvement. This work established the relationship between density waves and the deviation from ideal clarifier performance that earlier papers on internal waves from this research group suggested. The power spectrum of the internal waves and the effect of operating variables, such as overflow rate, scraper speed, and suspended solids, on the spectrum and solids removal were discussed.

B. Poster Presentation S36: "Parasites in Southern United States Sludges and Disinfection by Standard Sludge Treatment," by R. S. Reismers, M. D. Little, A. J. Englande, D. B. Leftwich, D. D. Bowman, and R. F. Wilkinson (U.S.A.)

The objectives of this study were to: (1) assess the presence and densities of resistant stages of parasites in municipal wastewater sludge (sewage) in the southern United States; (2) investigate parasite inactivation by lime treatment of sludges seeded with intestinal parasites; (3) measure the mass balance of helminth eggs through various processes in a municipal wastewater treatment plant; and (4) assess, on the basis of laboratory and field data, standard sewage sludge treatment processes for their effectiveness in inactivating parasites.

Sludge samples collected during each of the four seasons from 27 municipal wastewater plants located in Alabama, Florida, Mississippi, Louisiana, and Texas were examined for the presence and densities of resistance stages of human and animal parasites using parasitologic techniques developed for this study. Viable eggs of *Ascaris* and *Toxocara* were recovered at least once from every plant and viable eggs of *Trichuris vulpis* and *Trichuris trichiura* were recovered at least once from 26 and 15 plants, respectively. Viable eggs of at least 10 other helminths and cysts of a few protozoa were also found in fewer numbers and less frequently. Depending upon the parasite, the inactivation of parasites during sewage treatment fluctuated from season to season, but, in general, most were inactivated in the summer. Laboratory studies verified the results of previous investigations indicating that destruction of resistant parasite eggs is primarily due to temperature (heat) and not to a specific digestion process. Very large lime doses were required for the inactivation of viable *Ascaris* in sludges and results were not always consistent. Lime treatment thus appears to be an inexpensive but unreliable treatment for *Ascaris* inactivation. Laboratory experiments also showed that at certain combinations of ultrasonic frequency intensity and exposure time, *Toxocara* eggs could be destroyed, but that the same ultrasonic conditions did not affect *Ascaris* eggs.

An important finding of this study is the poor suitability of *Ascaris* eggs taken from the uteri of gravid female worms as indicators of the characteristics of *Ascaris* eggs discharged in the feces of the host. The eggs removed from the gravid females are not as resistant to adverse factors as eggs that have undergone a hardening process in the intestines of the host and been recovered from the feces.

C. Poster Presentation S37: "Water and Wastewater Treatment with Reusable Magnetite Particles," by N. J. Anderson, B. A. Bolto, D. R. Dixon, L. O. Kolarik, A. J. Priestley, and W. G. C. Raper (Australia)

A process was described which used finely-divided magnetite particles to adsorb negatively charged colloidal material. The basic advantages of the process, as compared with the conventional alum process, are its relative speed and simplicity. By adsorbing colloidal material directly onto the surface of a charged particle which can be rapidly removed from the water, the slow processes of floc growth and sedimentation can be avoided. Also, because of the high quality water which can be produced from the clarifier, there is no need for a subsequent filtration step.

The direct filtration process also avoids the slow floc growth and sedimentation steps and has some similarities with the magnetite process. Both involve charge neutralization and adsorption onto a particle surface. However, in the magnetite process, the particles perform a large fraction of the charge neutralization and are suspended in the liquid medium rather than being held in a fixed bed. This allows the particles to be continuously recovered, regenerated and reused, thus effectively creating a continuous filtration process. Consequently, the magnetite process is better able to handle the more turbid or colored waters which cause excessively short filter runs in a direct filter.

While the initial application of the process has been in the field of potable water, treatment of various industrial effluent has also been investigated. Satisfactory treatment was obtained in many cases and the magnetite particles were also able to adsorb phosphate anions, bacteria and viruses.

Research is continuing into the thermodynamics and kinetics of the interaction of various colloids with the magnetite surface in the anticipation that this will lead to further process improvements.

D. Poster Presentation S38: "A System Developed for the Treatment of Tanning and Fellmongery Effluents," by S. D. Roets (South Africa)

When Silverton Tannery decided to implement treatment on a full scale, it was decided to use flotation as a basis for further development of a system to obtain ultimate solid separation with minimum costs. As difficulties in several pilot plants developed regarding the control and implementation of dissolved air flotation, it was decided to experiment on the abandonment of dissolved air and pursue full-scale operation using foam flotation. A new concept called the Silflo System was introduced whereby some 20% of the clear effluent of the flotation unit was recycled for the production of foam. The foam is generated as a result of the mixing of air with an acidified effluent containing proteinaceous material. The addition of an acid was either in the form of a salt like ferric chloride or aluminum sulfate, or in the form of a liquid acid. Chemical addition not only precipitated the proteinaceous material, which was subsequently removed along with the other solids like hair fleshings, shavings and chrome particles, but also assisted in the production of a stable foam which acted as a support for these solids. A cationic polymer was added in the same line as the acid and foam to render the sludge hydrophobic so that interstitial water was released while the solids floated to the surface. The mixing of the foam and the polymer were achieved in the delivery line from a Mono pump supplying wastewater to the flotation unit. This made additional flocculation and coagulation facilities unnecessary.

The process was particularly effective for the treatment of tannery wastewater but could be extended to treat other types of effluents as well. Preliminary investigation showed promise in treating wastewater from abattoirs, chicken processing, general meat processing, paper mills, wetblue plants and fellmongeries. The COD, solids, sulfide and chromium in tannery wastewater can be reduced in excess of 90%.

E. Poster Presentation S39: "Research into Mass Culture of Algae in Closed Systems," by R. D. Walmsley, S. N. Shillinglaw, and D. Geldenhuys (South Africa)

In order to investigate the scaling up of algal cultures from the laboratory to the outdoors, some of the early work on mass algal culture involved the use of systems which were closed to the atmosphere. However, because nearly the entire work on algal mass cultures was restricted to open ponds, developments of closed systems over the past 30 years have been limited. The commercial exploitation of algal cultures is dependent on their integration into multi-use systems or utilization to solve environmental problems. In view of the possible benefits of linking closed algal culture systems with ethanol fermentation units, an evaluation of the concept of algal cultures in closed systems was presented as well as some design considerations for experimental ponds to be used in investigation of the feasibility of such a practice under South African conditions.

F. Poster Presesentation S40: "Utilization of Computerized Water Monitoring and Information Systems," by E. Ottmann (Federal) Republic of Germany)

In many countries automated water monitoring systems are installed and interesting reports have been published specifying required instrumentation, telemetering, and data acquisition and handling systems. Questions arise concerning the philosophy and the utilization of the equipment. Computerized water monitoring and information systems may serve several purposes including: providing data for hydrological services; improving the availability of data; enabling actual use and interactive communication and control; providing information for special tasks such as modeling prediction of various operations, monitoring conditions on overloaded rivers, or inspecting the performance of treatment plants and comparing this performance with the requirements of state or national laws. The resulting benefits in operation should be set against the costs of installation and the advantages of continuous measurement of parameters.

In hydrology, a description of the dynamic behavior of a water body and the associated water quality is needed. More specifically, supervision and control of automatically-merged information is necessary. It is now beginning to be appreciated that there are many tasks that cannot be fulfilled without the help of automation and computers. Besides the current and automatically sensed parameters, data must be integrated after sampling, lab analysis, and manual keyboard-input and must be considered as a whole for the purposes of management. Data acquisition may show how to differentiate between the various parts of a measurement network. Automated methods represent a small part of that total effort.

The monitoring network developed in Bavaria during the last five years utilizes a computerized information system that collects data from widely scattered points on rivers and offers evaluated information for users. Control of the automated system is carried out regularly by a process computer connected to field stations in Bavaria via dial-link lines of the public telephone network and with special parallel-serial codes. Reverse communication is available for remote controlling.

Automatic data acquisition from the field stations and the data input by teletransmission or keyboard provide the input to the system; on the other side is the output for users. The headquarters--a computer center--has to gather, prepare, calculate, and evaluate all the data before they are stored, for example, on disks and tapes. Users are then able to obtain all offered information and computer printouts or displays for any application from interactive graphic terminals. The defined objective of the system is information and communication, not merely water monitoring.

IV. CRITIQUE OF SESSION

The authors of Poster Presentation S35 presented an interesting paper dealing with the nonideality of settling in clarifiers. However, some of the conditions imposed in the model system limited the extent to which their results can be extrapolated to predict performance of the suggested improvements on full-scale clarification systems. The 1.2-m diameter clarifier size likely accentuated some of the hydraulic problems that exist in larger clarifiers. Additionally, a non-flocculating suspension in the concentration range 300-5000 mg/ℓ was used to monitor settling performance.

At influent concentrations of 1000 mg/ℓ and higher, the impact of the baffles was inconclusive over the range of reasonable overflow rates. Generally, the settling efficiency was lower than that typically experienced in practice, even though wind and thermal currents evidently were minimized in the experimentation. It appeared that adequate pilot-scale work has been performed in evaluating the proposed wave-trap baffling system. Detailed investigation of full-scale operating clarifiers should now be performed to verify the impact of the baffling system in improving clarifier performance.

A topic of significant practical value in the United States, because of the increasing trend toward land disposal of wastewater sludges was included in Poster Presentation S36. The approach followed a thorough and logical pattern that included the development of new separation and analytical techniques, and the application of those techniques to enumerating parasite densities in sludges. The sludges studies covered a spectrum of major sludge treatment approaches that are representative of typical practice in the United States. The study confirmed the resistant nature of parasites to these sludge treatment processes. It would be of interest to expand the scope of the study to include additional climatic regions and some other treatment methods, such as composting, that may be employed in conjunction with land application.

The process discussed in Poster Presentation S37 offered an intriguing alternative to conventional water clarification practice. By using a solid material to remove suspended material and color, the clarification process can theoretically proceed much more quickly and result in much lower solids quantities requiring ultimate disposal than with chemical coagulants. However, there appeared to be significant shortcomings to the process. Perhaps most important in the treatment of supply waters is the limitation on treatment efficiency. It appeared that the proposed process will not achieve acceptable product water color and turbidity levels in many instances. Additionally, it appeared that the critical magnetite-washing step may be difficult, particularly in wastewater applications. Finally, there is a definite tradeoff between reduced capital costs and increased power costs when this process is compared to conventional chemical clarification practice. This tradeoff needs to be evaluated very carefully in the context of life-cycle costing because of the escalation accompanying energy charges.

Poster Presentation S38 presented an interesting approach for pretreatment of selected industrial wastes that have high suspended solid and organic concentrations. The modified foam flotation process appeared to provide substantially better suspended solids removal than either gravity sedimentation or dissolved air flotation at the solids concentrations associated with the industrial wastes under study. However, a discussion of the mechanisms controlling the process was limited. As such, it is impossible to identify the parameters dictating process performance and to determine the approach to designing the process for treating wastes of differing constituent characteristics. More information is necessary relative to the range of variables evaluated and their impact on the efficiency of the treatment method.

An interesting assessment of an approach to maximizing a closed algal cultural system was presented in Poster Presentation S39. The system was designed to utilize an industrial CO_2 source, minimize evaporation, facilitate recovery of O_2 as a byproduct, and recycle the algal biomass to produce ethanol and protein for an animal feed supplement.

It was determined during the course of the research that closed systems have some drawbacks related to decreased light supply and high temperatures that develop. The reduced productivity associated with these system characteristics will have to be resolved if this type of system is to be practical, given the high capital cost relative to that of open systems.

Poster Presentation S40 described a specific circumstance involving the utilization of a computerized data collection and transmission system. While the system successfully addressed some historic communication problems related to Bavarian water resources, it did not appear to offer major new conceptual insights relative to data management.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

A relatively low-cost physical modification to wastewater clarifiers that would improve efficiency or facilitate higher hydraulic loadings would be a valuable improvement. The capability of the proposed system described in Poster Presentation S35 for achieving these goals has yet to be demonstrated.

The results of the study in Poster Presentation S36 are of immediate significance to American sludge disposal practice and should be expanded to cover a broader scope of conditions and practices throughout the country.

The magnetite process described in Poster Presentation S37 appeared to be undergoing continual refinement to address some of the indicated drawbacks and to expand the range of process applications. With additional process improvements, there may be some instance where this technology would be useful in the United States. However, it is doubtful that this process will revolutionize American clarification practice.

The problem addressed in Poster Presentation S38 is one that is common to the industrial sector in the United States. With the results and cost information presented, the proposed process warrants further investigation. It could provide another viable pretreatment alternative for a number of major American industries.

The specific application of algal cultural development pursued in Poster Presentation S39 has limited potential for impacting American water polluton control practice. Further, the concept of closed algal culture systems appeared to have several costly drawbacks that negate the potential benefits addressed in the research. Poster Presentation S40 does not appear to provide much new input to American water pollution control practice.

I. SESSION

A. Day: March 29 to April 2, 1982
Hall: Civic Center

B. Theme of Poster Presentations: Wastewater Treatment and Reclamation

II. REVIEWER

A. Name: Bruce A. Bell

B. Position and Affiliation:
Professor of Engineering
George Washington University
School of Engineering and Applied Sciences
Washington, D.C. 20052

III. DESCRIPTION OF POSTER PRESENTATIONS

A. Poster Presentation S5: "Flotation as the Final Clarification Step in Wastewater Treatment and its Influence on the Oxygen Balance of Receiving Waters," by K. P. Kiefhaber, U. Neis, and J. Weber (Federal Republic of Germany)

The poster presented a comparison of dissolved air flotation (DAF) and sedimentation for secondary clarification in a conventional municipal wastewater treatment plant. The poster then went on to calculate and present the effect of effluent dissolved oxygen concentration on the oxygen budget in the receiving stream based on the conventional Streeter-Phelps model.

The mixed liquor from a conventional municipal treatment facility was fed to parallel pilot-scale secondary clarifer and DAF units. Although not presented, discussions with Wolf revealed that the DAF unit was operated at a pressure of four bar at a 50% recycle of subnatent and without polymer addition. No sizing or operating parameters were available for the secondary clarifier. The use of sedimentation resulted in an overall plant BOD_5 reduction of 95%, an effluent turbidity of 5.4 FTU and an effluent dissolved oxygen concentration of 2.2 mg/ℓ. When DAF was used as the final solids separation unit, the overall plant BOD_5 reduction was 97%, the effluent turbidity was 3.3 FTU and the effluent dissolved effluent concentration was 5.2 mg/ℓ. No effluent suspended solids data were presented.

The effect of the discharge of the two dissolved oxygen concentrations resulting from DAF and flotation on the D.O. sag curve in receiving waters was modeled. As would be expected, the critical D.O. concentration was higher for DAF than for sedimentation. The time of flow to critical D.O. concentration was longer for DAF.

Virtually all the calculated effects on the D.O. sag curve resulted from the higher D.O. concentration in the effluent from DAF. Since this was pilot-scale work, no verification of the calculated D.O. effects was available. No data were available either in the paper or from the authors regarding reliability of performance or variations in operation of either process.

B. Poster Presentation S6: "The Disposal of Sewage Sludge by Land Spreading," by J. H. Nell and J. F. P. Engelbrecht (South Africa)

An overview of current land spreading practices and regulations in South Africa was presented as was a summary of current research into the effect of sludge application rates on metals and pathogen contents of crops grown and leachate. Land spreading is the major form of sludge disposal in South Africa. Of concern are heavy metals and pathogenic organisms. The paper summarized the regulations which use as a philosophical base the concept that sludge which contains no *E. coli*, *Ascaris lumbricoides* ova or pathogenic virus per 100 g is the only sludge which is unlikely to cause disease. As a result, digested sludge may be utilized only for fodder crops; pasteurized or composted sludges may be applied to crops for grazing, food trees, or crops which will not be eaten raw. Heat treated or physical/chemically treated sludge may be used on sports fields and crops for human consumption which may be eaten raw. The authors assert that these guidelines may be too stringent and may on the strength of current research, be relaxed in the near future.

Current research in lysimeter and plot experiments were summarized. In the lysimeter experiments, levels of K, Na, Ca, Mg, Ni, Pb and NO_3-N in the leachate correlated well with sludge application rates while Al, Cr, Co, Cu, Fe, Mn, Hg and B concentrations did not. Only Mg, Mn, Ni and Zi concentrations in the plants grown correlated with sludge application rates. Cadmium concentrations were less than detectable limits in all crops. The only indicator organism present on the crops was *E. coli*. Unfortunately, no data on sludge quality were presented in this work.

C. Poster Presentation S21: "Aspects of the Performance of Final Clarifiers in the Activated Sludge Process," by C. Davies (South Africa)

Several concepts in the design, monitoring and operation of secondary clarifiers in activated sludge plants was presented. The ideas presented were based on a combination of field trouble-shooting of clarifiers as well as full-scale experimentation on plants ranging from 1000 m^3/d to 150,000 m^3/d. All plants studied had anoxic or anaerobic zones for biological nitrogen or phosphorus removal.

The author recommended design be based on solids flux as well as overflow rate and that a flux of 6 $kg/m^2 \cdot hr$ is a safe peak design flux. Also recommended is a minimum 3-m sidewater depth. The author stated that poor inlet design can cause constant failures. Inlet designs which contain a forced change in direction of flow were recommended. It was also indicated that care must be taken to ensure that the gap between scum baffles and launders must be sufficient to avoid high local velocities. A minimum of 400 mm between the baffle and launder was recommended.

The SVI test was found to be of little value due to lack of stirring and wall effects. It was recommended that the initial settling velocity of the sludge be obtained by turning off aeration equipment for a short period of time and observing the rate of blanket settling. Data were presented showing that return sludge ratio has a profound effect on thickening with a recommended range of $0.5 \leq$ RAS ratio ≤ 4.0.

D. Poster Presentation S26: "Production of Algal Protein in Raw Sewage," by J. M. P. Viviers, E. Sandbank, L. R. J. van Vuuren, and A. Gerber (South Africa)

The work gives a superficial overview of work carried out in harvesting of algae from lagoons and drying of the product to produce a high protein animal feed. Harvesting of algae from treatment lagoons was carried out using dissolved air flotation (DAF) with alum and polymers. No data were presented or available through discussions with the author regarding DAF design or operation. The float was then dewatered with centrifugation and air drying. Again, no process design or operational parameters were available for these operations. The dried product was low in moisture (<10%) and ash (<10%) and contained 55% protein. Feeding tests are in progress with no results yet available.

E. Poster Presentation S31: "Exhaustive Recyclic Use of Water in the Food Industries," by R. A. Gallop, A. W. Hydamaka, B. J. Clark, and L. B. Carvalho (Canada)

The poster presentation presents virtually no data or current research. Rather, the authors present an argument for reuse of water in the food processing industry, particularly in the third world. Examples of reuse in the food industry were presented with particular emphasis on cascade processes where water was used from the last back to the first operation on the processing line.

IV. CRITIQUE OF SESSION

Poster Presentation S5 was focused on the effect of effluent dissolved oxygen concentration on the stream sag curve as calculated by the Streeter-Phelps model. There was no validation of predicted results.

Poster Presentation S6 presented an interesting overview of the practice and philosophy of land spreading of sludges. It is interesting to note that the authors expect a relaxation in the requirements as a result of current research. Research currently in progress indicated that only some parameters in leachate and plants can be correlated to sludge application rates. This is an area which should continue to be of research interest.

Poster Presentation S21 was excellent and was based on full-scale experience of design, monitoring and operation of secondary clarifiers. The value of the work is limited by the fact that only plants containing anoxic or anaerobic zones were studied. However, discussion with the author who was totally conversant with the subject helped extend the work beyond that formally presented.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Poster Presentation S5 raised a question which may be of interest to American researchers. Investigations into the cost effectiveness and benefits of DAF as a secondary solids separation process as opposed to sedimentation and reaeration for oxygen limited receiving waters may be beneficial.

Data presented in Poster Presentation S6 showing only partial dependence of leachate and plant qualities on sludge application rate offered opportunities for additional research. Also, the philosophical basis for land spreading regulation should be of interest.

Poster Presentation S21 points out very clearly the lack of knowledge regarding design, operation and monitoring of secondary clarifiers. Much work is needed in this area in order to provide design engineers and operators with useful information and procedures.

I. SESSION

A. Day: March 29 to April 2, 1982
Hall: Civic Center

B. Theme of Poster Presentations: Membrane Processes; Environmental Microbiology

II. REVIEWER

A. Name: George Belfort

B. Position and Affiliation: Department of Chemical and Environmental Engineering
Rensselaer Polytechnic Institute
Troy, NY

III. DESCRIPTION OF POSTER PRESENTATIONS

A. Poster Presentation S4: "The Application of Pre-Treatment Procedures to Limit Membrane Fouling in Reverse Osmosis Reclamation of Secondary Sewage Effluents," by H. A. de Villiers, G. R. Botha, and M. H. Wright (South Africa)

The authors reviewed the experience of the South Africa CSIR in operating a reverse osmosis pilot plant on sea water in Swokopmund, South West Africa (also called Namibia in the United Nations). Although they were not able to pinpoint the type of foulant resulting in significant flux-decline during operation, they discover a novel pretreatment method for reducing the degradative effects of this fouling. By allowing the feed to remain for several days in an open reservoir they discovered that membrane fouling was reduced. They qualitatively attribute this to UV-degradation together with possible biodegration. This pretreatment method, called the UVOX process, is now being intensely studied at the CSIR's National Water Research Laboratory in Pretoria.

B. Poster Presentation S11: "The Survival of Bacterial Indicators in Lysimeters and Landfills," by J. A. Donnelly, P. V. Scarpino, and D. Brunner (U.S.A.)

Data were presented on recovery of feed indicator bacteria from a 9-year-old commercial municipal refuse landfill and two 2-year-old lysimeters, one with municipal refuse and the other with hospital refuse. Total and fecal coliform and fecal streptococci were found in homogenized landfilled waste even though fecal coliforms and streptococci had disappeared two years earlier from leachate samples. It appeared that neutral pH values in the landfill provided favorable conditions for survival of the fecal bacteria since they were present in reduced numbers as the pH decreased from 7.1 to 5.2 with depth in the landfill. A number of Gram-negative rods were isolated.

C. Poster Presentation S12: "The Effect of Ionic Presence on Chlorine Disinfection of Animal Viruses," by S. Cronier, P. V. Scarpino, C. Wells (U.S.A.)

Information was presented on the influence of potassium and sodium on poliovirus I and Coxsackie A9 inactivation with free chlorine at pH 6 and 10 in the presence of several buffers. Data were also presented on these effects with combined chlorine. The amount of the inactivation at constant time and nearly constant residuals depended upon the amount and type of ion and the time of addition of the ion. These effects were noted for poliovirus I when hypochlorous acid, hypochlorite ion, monochloramine and dichloramine were used as disinfectants.

D. Poster Presentation S27: "The Enumeration of Streptococci and Mycobacteria Present in Landfill Leachate," by J. A. Donnelly, P. V. Scarpino and D. Brunner (U.S.A.)

Qualitative data were presented on recovery of streptococci and mycobacteria from leachate from a commercial landfill, pilot and benchscale lysimeters. These had received either municipal refuse, mixed refuse and sewage sludge or mixed hospital and municipal waste. Mycobacteria concentrations varied from 1/100 mℓ to 33/100 mℓ of leachate with eight groups found in at least one sample. A variety of streptococci were found but with less species diversity in older landfills indicating a die-off of some strains.

IV. CRITIQUE OF SESSION

Poster Presentations S11 and S27 dealt with a similar problem--microorganism survival in sanitary landfill. Similar data have been presented from other studies in the United States. The mycobacteria findings may be new but were not unexpected. The authors did not state from which waste these mycobacteria were isolated. The brevity required in posters precludes the presentation of sufficient data to answer many of the questions which arise.

It appeared that all, or nearly all, of the data in Poster Presentation S12 have been presented in other papers. These data, while real, have not been shown to be much more than a laboratory curiosity. The salt concentrations of interest in these studies are beyond the range usually experienced in water disinfection practice. It would seem useful to attempt to determine the mechanism which causes this effect. If this were known it would then be possible to extrapolate the known data to other situations without the need to do another study.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The information in Poster Presentations S11 and S27 reinforced the known facts on biological hazards from landfill leachates. These leachates are crude materials and their known pollutional effects must be considered in developing downstream groundwate supplies or in locating surface disposal points.

The disinfection data in Poster Presentaton S12 were of limited application value in the usual situation. Where there are odd salt conditions in the waste to be handled, it would be well to consider the phenomenon discussed in this poster.

CHAPTER III

OVERVIEW OF PERTINENT CONFERENCE DEVELOPMENTS

In this chapter, pertinent developments at the Conference as reported by individual participants are briefly summarized and categorized. The chapter represents primarily a summary of Chapter II. However, the chapter also contains a summary of other observations made by individual participants regarding international developments of potential interest to U.S. water pollution researchers which did not emanate from the formal program of the Conference.

DEVELOPMENTS AT FORMAL SESSIONS

This section highlights the individual reports contained in the previous chapter by reviewing the more significant observations and conclusions according to various categories of water pollution research interest. In each case, comments are identified by the paper number or workshop title to which the observations relate. Comments included here may not necessarily be contained in the formal papers but may have developed from discussions at the Conference. Paper numbers and workshop titles are included to facilitate reference to the more extensive analyses of Conference developments included in Chapter II. By referring to the paper or workshop of interest in the Table of Contents and Key to Reviews, the location of the corresponding discussion in Chapter II may be determined.

Analytical Techniques

Detailed procedures for the measurement of wastewater phenolic compounds in domestic wastewaters and sludges using capillary GC/MS/DS techniques were presented (Paper No. 30, U.S.A.).

The use of a thermally-modulated electron capture detector, i.e., two electron-capture detectors in series with a catalytic pyrolysis unit, in conjunction with two-dimensional gas chromatography, were presented as an emerging analytical procedure. The technique was shown to be useful in identifying haloacetylnitriles and trihalomethanes in drinking water (Paper No. 16, U.S.A.).

A membrane diffusion cell was described for use in monitoring for dissolved nitrogen (N_2) in environmental waters using a gas chromatography system (Paper No. 18, Norway, U.S.A.).

Physical-Chemical Treatment

Chlorine reacted with three different organic bases in different ways (Paper No. 35, U.S.A.). Current ability to anticipate reaction products is limited.

Slow sand filtration systems were shown to be effective means of controlling the cercariae (*Schistosoma mansoni*) of human schistomes (Paper No. 17, U.S.A.)

Ultrafiltration was successfully used to recover PVA from a textile wastewater following pretreatment using filtration or centrifugation to remove small fibers (Paper No. 45, South Africa).

Techniques using a simulated flow cell for the characterization of fouling potential of pressure-driven membrane processes was presented. The flow cell was shown to be useful in predicting fouling characteristics for a reverse osmosis membrane system (Paper No. 19, U.S.A.).

A magnetic ion exchange resin can be used to demineralize water and wastewater with a TDS of 500 to 2000 mg/ℓ at an 80% efficiency. Regeneration of the resin requires only the addition of low-grade heat for removal of exchanged ions (Paper No. 21, Australia).

Macroporus resins in a strong cation/weak anion sequence were used in a continuous counter-current ion exchange process for demineralization of wastewaters and brackish water (Paper No. 23, South Africa). The use of magnetic ion exchange resins and the continuous counter-current ion exchange process have the potential to eliminate fouling problems associated with reverse osmosis treatment of wastewater effluent.

Use of ozone prior to slow sand filtration was found to improve heavy metal removal in the filter (Paper No. 37, France). It was speculated that ozone solubilizes particulate metals and breaks organic complexes to create free metal ions which are more readily removed.

Preozonation of effluent was demonstrated to extend activated carbon life and improve removal (Paper No. 33, U.S.A.). Similar results were reported by South African and Swiss workers.

pH was shown to be a critical parameter affecting the rate at which aromatic compounds are oxidized in the ozonation processes. Ozonation of naturally-occurring and anthropogenic compounds were both shown to be enhanced with elevated pH values (Paper No. 28, Federal Republic of Germany).

The magnetite process can theoretically allow the clarification process to proceed at a much faster rate but may not produce acceptable color and turbidity in the final effluent (Poster Presentation S37, Australia).

Fixed Film Biological Reactors

Modeling of fixed film biological reactors received appreciable attention (for example, Paper No. 59, France; and Paper No. 61, Japan and Thailand). Participants were critical, however, of oversimplifications contained in the models.

Effects of turbulence and other factors controlling transfer of oxygen to the bulk liquid of rotating biological contactors (RBC) were shown to become relatively less significant as the size of RBC units increases (Paper No. 27, U.S.A.). Most oxygen transfer occurs through the biofilm.

The resistance to outward diffusion of bicarbonate and carbonate ions was shown to cause elevation of pH in biofilms used for denitrification (Paper No. 63, Denmark).

Results from a study on mass transport within biofilms (Paper No. 25, Japan) contradicted earlier results and necessitates additional research.

Nitrifying organisms in fixed film reactors were found to be generally less sensitive to inhibition than those in suspended growth reactors (Paper No. 57, France).

A mathematical model for predicting the performance of aerated activated carbon biofilters was presented (Paper No. 31, France). At low organic loadings, continuous biological regeneration occurs, but at high loadings biological growth hinders adsorption and leads to clogging.

Installation of rotating biological contactors in modified primary settling tanks was described (Paper No. 5, U.S.A.).

Suspended Growth Biological Reactors

Use of the Marais-Ekama model to predict performance of full-scale activated sludge plants was reported (Paper No. 29, South Africa). Reasonable predictions of COD, TKN, ammonia and nitrate concentrations were considered to be obtained.

Two very similar systems for nitrogen removal by biological nitrification and denitrification in a single-sludge system were reported. The treatment processes were developed independently in South Africa (Paper No. 8) and in Japan (see discussion of Paper No. 8).

Control of bulking in the activated sludge process may be achieved by control of process configuration (Paper No. 2, U.S.A.). Use of an initial "selector" containing 1/74 of the aeration tank volume was successful. Causative mechanisms are not yet understood, but removal of dissolved substrate in the selector seems to be important. There seemed to be general agreement among conference participants that basin configuration plays an important role in control of filamentous bulking.

A two-stage high-rate algal wastewater treatment system was shown to remove wastewater nitrogen to a level of 4 mg/ℓ and phosphorous to less than 0.5 mg/ℓ. This use of micro-algae for nutrient extraction was also shown to effectively remove other growth factors which stimulate algal growth in the natural environment (Paper No. 20, Israel).

Anaerobic fermentation was shown to be effective means of treating potato-processing wastewaters (Paper No. 41, Australia).

Work in South Africa (Poster Presentations S17, S18, and S33, South Africa) has developed a rational basis for design and operation of activated sludge plants for phosphorus removal without chemical addition. *Acinetobacter* was established as the primary biological agent. Research established that totally-anaerobic conditions must precede aerobic tanks for the excess phosphorus removal to occur. This combination is not accomplished in the typical Bardenpho-Phoredox type plants. Their work indicated that *Acinetobacter* gained a growth advantage when anaerobic conditions are present. Chemical removal of phosphorus in biofilms was investigated in a laboratory study (Poster Presentation S32, Denmark).

Sludge Treatment, Utilization, and Disposal

Clinker formation in multiple hearth furnaces was found to be associated with high temperatures and long residence times. Volatilization of cadmium from sludge incinerated in a multiple hearth furnace was reported to be increased at higher temperatures, but most of the cadmium was recovered in scrubber water (Paper No. 11, Canada).

The potential use of rheological measures to identify optimal sludge conditioning dosages was described (Paper No. 14, Canada).

Pasteurization of sludge using submerged combustion of digester gas before anaerobic digestion was reported (Paper No. 51, Federal Republic of Germany). New German regulations will require pasteurization or equivalent treatment of sludge applied to pastures beginning in 1986.

Because of high capital costs and low efficiency of energy recovery, anaerobic digestion was considered to be inferior to thermophilic aerobic digestion at small installations (Paper No. 49, Federal Republic of Germany).

Wall growths were found to have appreciable influence on the performance of laboratory-scale anaerobic digesters (Paper No. 53, Portugal and United Kingdom). In inhibition studies, it was found that removal of wall growths caused failure conditions to be reached more readily.

Recycle of magnesium from sludge produced by precipitation of phosphorus with lime was reported (Paper No. 39, Israel). The magnesium serves as a flocculant and lime dosage is reduced.

An attempt was made to identify design and operational practices that lead to integrated systems of sludge management with low cost (Paper No. 55, U.S.A.). Short mean cell residence time in the activated sludge process, large thickeners, and ocean disposal favor cost reduction. The mode of sludge transportation used has a very significant effect on costs.

The role of cationic polyelectrolytes in flotation thickening of conditioned activated sludge was presented. Molecular weight and ionic charge were indicated to be significant variables (Paper No. 43, Canada).

Metal phosphating and pickling sludges were extracted using distilled water in a lysimeter to determine long-term effects of leaching from a segregated landfill (Paper No. 47, U.S.A.).

Current South African regulations for land spreading of sludges are based on the philosophy that only a sludge with no *E. Coli*, *Ascaris* ova or pathogenic viruses is one unlikely to cause disease (Poster Presentation S6, South Africa). Current research in South Africa is directed to developing data on safe levels of these agents, as well as for metals, for spreading or land use for various purposes. *Ascaris* ova were found to be resistant to inactivation by major sludge treatment methods (Poster Presentation S36).

Wastewater Reclamation

Operational performance of wastewater reclamation plants at Stander and Pretoria, South Africa and Windhoek, Namibia was reviewed (Paper No. 3, South Africa). Experience at the Windhoek plant, in particular, had proved the practical feasibility and safety of direct reclamation of wastewater for potable uses. For example, using a hamster cell transformation assay, reclaimed water from the Windhoek plant was shown to have a quality similar to that of an excellent drinking water, as far as content of potential carcinogens and toxicants (Paper No. 6, South Africa). In addition, using extensive chemical analysis of volatile halogenated hydrocarbons, chlorinated hydrocarbons and pesticides, chlorophenols, PAH, and phenolic compounds, the finished chlorinated water of the direct reuse system at Windhoek was judged to be of high quality and better than that of an indirect reuse system using water from a surface water source (Paper No. 9, South Africa).

Treatment requirements for use in recycling wastewater are dictated by the intended use of the wastewater, institutional considerations and limitations, economic issues, and health considerations and quality criteria. Use of aquifers for storage for reclaimed wastewaters does not eliminate monitoring problems since, if a deleterious substance is discovered prior to distribution, a public health problem is eliminated but a useful aquifer is contaminated (Workshop-Theme 6).

The use of water recycling techniques by numerous industries in Germany was presented. The consensus of South African opinion regarding potable reuse of wastewater was that indirect and unplanned reuse of water containing effluents and planned recycling of reclaimed wastewater for potable purposes were essentially identical. Implementation of new standards for direct reclaimed wastewater were not considered to be necessary (Workshop-Theme 6). Although there is considerable concern in many countries regarding the need for additional research on characterization of reclaimed wastewaters prior to potable reuse, countries where water resources have become limited have taken the position that some risks associated with reuse of reclaimed wastewater must be taken and that all issues regarding potable water quality need not be known.

Issues regarding mineralization of surface water supplies due to continuous dewatering of gold mines, dissolution of salts from mine rocks and sand dumps and sewage or industrial wastes was discussed in detail. Examples of types of costs and impacts considered and treatment systems to be used to prevent mineralization were presented (Paper No. 12, South Africa).

Monitoring Systems and Strategies

Use of fish for continuous biological monitoring was advocated (Paper No. 32, South Africa), and it was indicated that 10% of the lethal level could ordinarily be detected.

A long-term survey, conducted in the surf waters near Durban, South Africa, was used to indicate improvements in bacteriological quality of surf waters over a ten-year study period resulting from improvements in wastewater treatment systems (Paper No. 1, South Africa).

Sharks were shown to be excellent indicator organisms for monitoring heavy metal pollution, especially copper, lead, zinc and mercury. Initial data indicate that sharks may also be excellent organisms for use in monitoring for such organic compounds as PCB, DDE, DDT, dieldrin and camphloclor (Paper No. 7, South Africa).

A comprehensive predischarge base-line study in conjunction with long-term postdischarge surveillance program for a nickel refinery was presented. It was concluded that since species diversity may vary seasonally as a result of species interactions, climatic variations and spacial heterogeneity, extensive predischarge studies must be conducted in conjunction with long-term postdischarge monitoring. The natural cycles of species making up a population must be considered when conducting environmental monitoring programs (Paper No. 10, Australia).

High toxicity of polyelectrolytes to fish was demonstrated in a study originally designed to test a dynamic testing apparatus (Poster Presentation S14, Canada). These chemicals, used in wastewater treatment, may be potentially hazardous to aquatic life in receiving waters.

Microbial Resistance of Indicator Organisms

The ability of microorganisms to adapt to unfavorable environment conditions and the selection of resistance of microbial strains were discussed in detail. Data indicating the mutation of *E. Coli* type II to *Citrobacter freundii* types I and II were presented and questioned by conference participants. Considerable discussions were focused on factors associated with adaptation of a microorganism as opposed to the production of genetically-stable mutations in an unfavorable environment (Paper No. 24, Japan).

With regard to resistance of indicator microorganisms to combined chlorine, *E. Coli* was a predominant organism isolated from unchlorinated sewage treatment processes and ranked fifth of twelve genera in resistance to combined chlorine. *E. Coli*, however, was not found in chlorinated tertiary effluents and *Enterobacter* species were the most dominant organisms. Issues regarding mechanism and extent of chlorine resistance were discussed in detail. Considerable concern was noted over the potential for development of chlorine-resistant microbes, both indicator microorganisms and pathogenic microorganisms. The question of the need for chlorination of wastewater effluents was seriously questioned (Paper No. 26, U.S.A.).

Mutagenic Activity

Water samples were analyzed directly following filtration (0.22 μm membrane filter) with hamster cells to monitor for potential carcinogens and toxicants using transformation assays. Transformation and survival were determined by counting colonies after an eight-day incubation period using benzo-a-pyrene as a positive control (Paper No. 6, South Africa).

Mutagenic activity, as determined by the Ames test, was consistently found in concentrated samples from 14 of 19 sampling points in Pretoria's drinking water sources (Paper No. 34, South Africa).

Virus Inactivation and Removal

Model enteroviruses were shown to be removed during filtration in conjunction with fine turbidity particles, indicating adsorption to turbidity particles was responsible for a major portion of virus removal. In addition, alum addition enhanced adsorption of viruses to coagulant particles and their subsequent removal (Paper No. 48, India).

Enteroviruses were effectively removed with an automated hollow-fiber ultrafiltration system using polysulfone membranes (pore opening of 250 μm). Membrane-adsorbed viruses were not recovered using permeate alone for backwashing but were successfully removed using pH buffers and glycine (Paper No. 50, U.S.A.). Adsorption of enteroviruses from sewage was successfully achieved by adsorption onto preformed aluminum hydroxide flocs (Paper No. 52, Brazil). Enteroviruses were successfully recovered from drinking water and river water samples at recoveries of 30% to 41% using glass powder with diameters of 100 to 200 μm (Paper No. 54, France).

Regrowth of bacteria in ozonated drinking waters was attributed to production of aldyhydes and ketones during the ozonation process. Addition of chlorine with ozone retarded, but did not eliminate the regrowth. Ozonation, furthermore, was shown to markedly reduce the potential for generation of trihalomethanes on subsequent chlorination of drinking waters (Paper No. 56, Switzerland).

Ozone was shown to effectively destroy the structural integrity of bacteriophage T4 at doses of 0.2 - 0.5 mg/ℓ in two minutes or less. Electron microscopy data indicated that rapid fragmentation of released DNA occurred within this time period (Paper No. 58, U.S.A.).

Eutrophication

A Water Quality Index was used to indicate improvements in water quality in an urban reservoir resulting from the termination of nutrient flow from an influent wastewater treatment plant (Paper No. 60, Federal Republic of Germany).

A two-year study of an urban catchment was conducted to determine the means of import and export of nitrogen, phosphorus, COD, BOD, and heavy metals. Atmospheric deposition accounted for virtually all of the soluble nitrogen contained in storm water transport but accounted for less than half of the other materials in runoff. The use of the unmodified SWMM model produced excellent runoff hydrographs but failed to predict the transport of pollutants in storm water. This lack of correlation was attributed to the lack of appropriate atmospheric deposition rates in the model (Paper No. 62, South Africa).

The treatment of the total flow of an influent river to a major reservoir in Bonn, Germany using chemical precipitation, flocculation and filtration was successful in reducing total phosphorous content from 100-150 μg/ℓ to approximately 5 μg/ℓ (Paper No. 15, Federal Republic of Germany). Treatment of the total river influent to the reservoir reduced reservoir phosphorous concentrations from approximately 25 μg/ℓ in 1970 to 11 μg/ℓ in 1980. Considerable reductions in reservoir biomass, chlorophyll-*a* and transparency of the reservoir were achieved.

Algal growths in the Ruhr River occur to the extent that stream aeration is required and water treatment plant capacity is affected. Phosphorus is the limiting nutrient and a source control program has been implemented (Paper No. 38, Federal Republic of Germany).

Raw Water Quality

Studies conducted to determine causes of taste and odor in natural river waters must include comprehensive monitoring of inorganic and organic constituents as well as detailed evaluations of resident algal populations (Paper No. 13, France).

The concentration of nitrates in the Thames River increased from an average value of 4.2 mg N/ℓ in 1968 to 7.7 mg N/ℓ in 1979, and based on model projections, it will be 9.8 to 15.5 mg N/ℓ by the year 2000. A new European Economic Community Directive establishes a maximum permissible nitrate concentration of 11.3 mg N/ℓ (Paper No. 46, United Kingdom).

Oil

The Federal Republic of Germany subsidizes collection of lubricating oils. In France, prices paid for waste oils are controlled and disposers are licensed (Workshop-Theme 2).

The convener of a State-of-the-Art Workshop on Oil Pollution in Marine and Fresh Water Environments concluded that (1) existing international agreements must be made more effective; (2) sources of oil pollution cannot be considered apart from effects; (3) adverse local effects must not be underestimated; (4) the question of whether a few supertankers are more desirable than a larger number of small tankers remains unresolved; and (5) available oil pollution abatement technology is improving (Workshop-Theme 2).

Sediments

Use of a rotating annular channel to measure the depositional properties of silts in bays and estuaries was described (Paper No. 36, Japan).

It was reported that the potential for phosphorus release from sediments is indicated by the amount of phosphorus released by extraction with sodium hydroxide (Paper No. 42, Japan). This phosphorus existed as iron or aluminum phosphate or it was adsorbed.

Large quantities of phosphorus can be stored in oxygenated surficial sediments and subsequently released during anaerobic conditions (Paper No. 44, U.S.A.). The primary mechanism is anaerobic destruction of insoluble ferric iron compounds with release of sorbed and precipitated phosphorous species.

Mathematical Modeling

The state-of-the-art workshop identified pitfalls in mathematical modeling in monitoring water pollution as including poor communication between modelers and decision makers, use of sophisticated models for the solution of simplistic problems, and lack of adequate model verification (Workshop-Theme 1).

Technology Transfer

Major needs in the area of technology transfer were identified (Workshop-Theme 4). Improved communication between researchers, consultants, equipment manufacturers and operating personnel was identified as a major requirement for successful improvement in transfer of new and developing technologies.

The scaling of reactor systems from laboratory and pilot-scale systems to full-scale wastewater treatment systems was indicated as a major research need in the area to technology transfer (Workshop-Theme 4).

Nuclear Power Plants

A study of the significance of a nuclear power reactor on water quality in rivers subject to low flows was reported (Paper No. 40, Belgium). Reduction in flow, thermal impact, discharge of radioactive material, and enrichment in salts and suspended matter were considered.

Developing Countries

The state-of-the-art workshop on water pollution control in developing areas emphasized appropriate regulations, training, and appropriate technology (Workshop-Theme 5).

Pollution Control Funding

The same problems of funding for pollution control activities exist throughout the world. Reasons for the difficulty in attaining funding must be established in order to achieve progress in water pollution control (Workshop-Theme 3).

DEVELOPMENTS OUTSIDE OF FORMAL SESSIONS

Much of the beneficial exchange of technical information occurring at professional meetings takes place outside of the formal sessions. At international conferences, the opportunities for such effective information transfer are considerable. Recognizing this potential, participants in the development of this report were asked to submit comments obtained from such interactions with water pollution researchers from other nations. Comments of possible interest to U.S. water pollution researchers, not part of the formal conference program, are summarized in this section. These comments have been identified with an individual participant and do not necessarily reflect the views of USANC.

Coal Gasification Wastewater Treatment

Several observations and comments relating to this topic were presented in the main body of the report and are not repeated here relating to water pollution control at South Africa's SASOL II coal gasification plant near Secunda. SASOL is the acronym for the South African Coal, Oil and Gas Corporation. It represents the largest synfuels operation in the world and is presently meeting close to 20% of the petroleum demands of the country (Heaton).

SASOL I, located at Sasolburg and southwest of Johannesburg, has been converting coal to gaseous and liquid products since 1957. SASOL II was completed in 1980 at a cost of approximately $2.5 billion and is near Secunda, which is east of Johannesburg. SASOL III, a mirror image of SASOL II, began operation this year at the same site and was built at a cost of $3.5 billion.

Little detailed information is available, such as output, actual costs and government subsidies because of national security issues. However, the following information was made available on the scheduled tour (Wednesday, April 7, 1982) to SASOL II:

(1) Gasoline at service stations sells for 66¢/ℓ and SASOL technology is competitive at this price. When the plants were built, it was not and the management depended heavily on inflation and increases in world oil prices to justify construction. Their attitude toward our United States synfuels industry is that, "If we don't do it now, we'll never do it." However, South Africa is in a unique position in that they have no natural oil and few friendly nations with which to trade.

(2) Coal is one answer to their energy situation and several hundred years of good anthracite supplies are available as in the United States.

(3) Much has already been done to establish a South African framework to promote the synfuels industry. It has government assurance (adhering to their 40-year-old principle) that prices of indigenous products will be allowed to follow international oil prices.

(4) Effective synfuel projects require huge capital investments and a long period between investment and income stages. It was their conclusion that this was still the major obstacle to worldwide alternative fuel projects. It is generally accepted in their country that the synfuel industry requires more government involvement than mere rate protection.

(5) In the South African context, it is necessary for government to assume the role of temporary entrepreneur in partnership with private investors as was the case of SASOL II and III. The relative scale of participation would depend on requirements of the investors involved. The government, in due course, will earn a realistic return on its investment in the forms of interest, dividends and capital gains. Original investments in SASOL I, which commenced in the 1950's, not only earned dividends but were repaid sevenfold in 1979.

(6) SASOL IV will probably not be considered until the 1990's. Manpower and training are more critical problems than initial financing and technology. SASOL II and III were the biggest industrial projects on one site ever undertaken in the world.

(7) SASOL II alone will mine 27.5 million tons of nearby coal annually with a 70-year useful life; 40,000 ton/d are consumed in the process to produce approximately 55,000 barrels of fuel.

(8) The basic overall procedure of the coal gasification/liquification process is to combine crushed coal with steam and pure oxygen to form raw gas for upgrading into petroleum and other chemical products. Computerized control is used throughout. Thirteen thousand (13,000) tons per day of O_2 are produced at SASOL II, the largest plant in the world.

(9) Very important to the overall economics of the system is by-product recovery and marketing of sulfur, phenols, ammonia, alcohols, ketones, ethylenes, LPG, waxes, tar products, and solvents. Several industries have developed around SASOL to produce materials from these feedstocks, e.g., plastics, fertilizers, and explosives.

(10) In comparison with United States oil-shale processing, the SASOL system is perhaps 50% more complicated and technically difficult with concomitant increases in cost.

(11) The plant was constructed 58 km from the nearest water source and 160 km from the nearest feasible wastewater discharge point. Thus, a zero-discharge situation was mandated from the beginning. A dam was built on the upper Vaal River and water was piped to the complex. Eventually, 95×10^3 m^3/d of water will be withdrawn and consumed at SASOL II and III. Seventy percent of the water is used for cooling purposes and the remainder is used to produce steam as follows: 10% for gasification; 10% for electrical generation; and 10% for general purposes and heating. Insufficient electricity is generated onsite and power is purchased from nearby coal-fired plants.

(12) Two separate water systems are employed in the plant: (a) raw water/utility cooling/boiler feed water treatment; and,(b) wastewater upgrading and process cooling. In the first system,(a), raw water is brought to SASOL via gravity flow from the dam. Clarification occurs in settling basins and the water used directly in hyperbolic utility cooling towers which serve the steam and oxygen plants. Two or less concentration cycles are used, then the water is taken to the boiler-water preparation facility. Three qualities of water are produced for various boiler feeds from the following treatment steps: hot-lime softening and sodium ion exchange for steam plant boilers; hot-lime softening and demineralization plant for waste heat boilers; and hot-lime softening, demineralization and ion-exchange polishing for high pressure waste heat boilers. Careful control is maintained to eliminate any oily wastes from this water loop.

The second or effluent upgrading system,(b),is entirely distinct and separate from previous processes. All wastewaters, process effluents, storm waters, oily sewers and domestic sewage are collected and treated by the activated sludge process. Calcium flouride was previously precipitated with lime but has been discontinued. The biological process is used to nitrify and denitrify in several stages but has not been achieved because of the highly variable nature of the feeds. Solids are centrifuged and incinerated onsite. The biologically-treated (BIOX) effluent is filtered and subjected to activated carbon adsorption for COD removal, then treated by ion exchange for soluble salt reduction. Carbon regeneration is accomplished onsite. Treated water is consumed in two hyperbolic process cooling towers after four cycles of concentration. Brines are taken to a thermal concentrator and disposed of in abandoned coal mines or the ash piles.

(13) The ultimate disposal of waste products will be in coal-ash piles. Literally, mountains of the material will be created around the flatlands of SASOL II and II and contain brines and all hazardous wastes. Eventually, the piles will be revegetated with seepage water recycled.

(14) Corrosion became a severe problem in the second water loop (i.e., 12(b)) and cooling tower life was reduced to one-two years. The only solution, thus far, has been to use chromate inhibitors. Careful monitoring of the biological system (BIOX) is taking place to note the effects of chromate poisoning on biological growths.

(15) Two important factors come from the SASOL technical tour as related to water balances and treatment at Colony. Their BIOX system does not operate as designed or meet their expectations. This was a result of inadequate or practically non-existent pilot work because of time constraints in development. In start-up operations, tremendous quantities of water were created before equilibrium could be achieved. It is important to have adequate storage for these waters which will then be returned to the evaporative system over a long period of time (Heaton).

Pollution control technology in the United States synfuels industry is a new field. Zero discharge mandates extensive treatment and recycling technology and the waste products are unique. Increased research by private concerns, DOE and EPA is necessary to allow closed-loop operations and evaluate the delicate balance between environmental regulations and national energy needs (Heaton).

The SASOL I facility treats synthetic fuels wastewater in conjunction with municipal wastes in a system incorporating biological filtration and disposal via a slimes pond. Regulations for the SASOL II and SASOL III complexes are different than that for the SASOL I complex (Neufeld).

Research is underway at SASOL to examine questions of water reuse via advanced waste treatment technologies paralleling that being conducted at major universities in the United States. The SASOL complex, however, is capable of using larger pilot facilities than those in the United States since limitations of wastewater availability, as experienced by American universities and DOE, do not exist in South Africa. A need exists to develop better criteria for reuse water quality, and for linkages of processes for treatment. Disposal via evaporative cooling is being considered. Since South Africa is a dry climate, disposal of cooling tower blowdowns on land is a viable approach which may not be applicable in the United States (Neufeld).

Biological Wastewater Treatment

The use of fixed film systems, particularly RBCs, are becoming widespread throughout Europe and Africa. Many RBC plants in South Africa are greatly simplified as compared to those being built in the United States. Most of them are being constructed to provide nitrification as well as for organic removal (Bishop).

Biological fluidized bed treatment systems are receiving much attention in the United Kingdom and several experimental full-scale systems are in operation (Bishop).

The impact of high energy costs has led engineers and operators to look to more efficient aeration systems. The Water Research Centre at Stevenage, United Kingdom, is currently performing demonstration studies at Rye Meads to demonstrate the low use of energy, consistent quality of effluent and reliability, flexibility, and cost-effectiveness of using fine-bubble diffused aeration (Boyle).

Ebera-Infilco (Ebera-Infilco Research Center, Fujisawa 47-20, Fujisawa-shi 251, Japan), M. Kitagawa, K. Watanabe, and M. Kobayashi have developed and tested, on a pulp and paper waste, a new modification of the activated sludge process termed "Bulking Free Process" (BFP). In the process the recycle activated sludge (RAS) stream is split; a small fraction (approximately 5-10%) is conveyed to a small initial aeration basin where it mixes with influent wastewater. The bulk of the RAS is fed to a larger aeration basin that receives the effluent from the small initial aeration basin. The organic loading on the initial aeration basin should be >5 kg BOD/kg MLSS-day (Jenkins).

The Water Research Centre in Stevenage, United Kingdom, is in the process of conducting a demonstration study on the use of the Simon-Hartley Captor process. The Captor process employs 2.5 cm by 2.5 cm by 1.25 cm plastic porous pieces in an aeration tank. This "fixed" suspension growth system is capable of concentrating biomass in a small reactor volume. The project will be reviewing the efficacy of this process in the carbonaceous stage of [illegible] two-stage nitrification system (Boyle).

Commercial sector activity is increasing in the area of developing fluidized bed, expanded bed, and fixed film/suspended film hybrid systems for the biological treatment of carbonaceous and nitrogenous materials. Commercial scale systems, applied in France, have been piloted on an "in/out" basis with relatively low levels of fundamental modeling support. Many have agreed that a need exists to develop and apply theoretical models of such hybrid systems to pilot-scaled facilities for confirmation and calibration (Neufeld).

Eutrophication

Interest in eutrophication continues to be widespread throughout the world. In particular, the impact of eutrophication on the quality of raw water sources for municipal supplies is receiving increasing attention. The importance of making careful nutrient budgets to give full consideration to internal as well as external sources of nutrients is more widely recognized. The need for a better understanding of the extent of internal sources is justified, because as external sources are brought under control, internal sources may have a major influence on eutrophication. As phosphorus becomes more widely controlled, the control of nitrogen is receiving increasing attention (Rohlich).

Phosphorus Removal

Interest continues over the most cost-effective methodology for removing nutrients from wastewater. Research emphasis has shifted from physical-chemical to biological methodology. Significant discussion occurred and some controversy developed while dealing with mechanisms and optimal design for biological nitrogen and phosphorus removal (Englande).

There are 30 existing plants in South Africa in which phosphorous removal is practiced. Of these, 15 are of the multi-stage activated-sludge Bardenpho type. A survey of 11 of these plants showed that only one was meeting secondary effluent levels of 1 mg P/ℓ. The major problem appeared to be in lack of anaerobic conditions in the anaerobic basin due either to the presence of nitrates (i.e., COD/TKN ratio is too low) or DO (aeration of RAS and waste streams by screw pumps or in channels). Low COD/TKN ratios were often produced by primary sedimentation that removed proportionately more COD than TKN. Suggested remedies involve bypass of primary sedimentation and addition of acid-fermented primary sludge (Jenkins).

A visit to the Bardenpho plant at Goudkoppies, Johannesburg, revealed: (1) Significant activated sludge settling problems (SVI 200-300 mℓ/g) likely due to anaerobic and anoxic basins in the treatment system; (2) significant *Nocardia* foaming; (3) the COD/TKN ratio of the waste had been increased by diverting to the plant a high-COD yeast waste; (4) there was considerable short circuiting of the anaerobic basin and back mixing of aerobic and anoxic basins due to aerator placement; (5) the effluent quality after the first aerobic basin was the same as that following the second aerobic basin. It is concluded that, in this case, the second pair of anoxic/aerobic basins were not needed; (6) the plant is run with manual control because it was found to be impossible to run it on automatic control using DO sensors (Jenkins).

A post-conference seminar in Pretoria on Biological Phophorus Removal reached the following conclusions on generally accepted knowledge concerning enhanced P removal in biological waste treatment systems. With respect to biological mechanisms: (1) enhanced P removal is due to polyphosphate accumulation in bacteria or chemical precipitation or both; (2) enhanced P removal via polyphosphate accumulation requires that the activated sludge has been through an anaerobic fermentation stage; (3) the anaerobic fermentaton unit processes organic matter either directly from the sewage or from the activated sludge itself; (4) for plants incorporating nitrogen removal the following must hold for successful biological P removal: COD/TKN ratio > 10; (5) there was agreement that the cations K^+ and Mg^{2+} accompanied the biological uptake and release of P (Jenkins, Randall).

With respect to chemical mechanisms, the following conclusions were established: (1) chemical precipitation is promoted by relatively high concentrations of P, and cations of [Ca^{2+}, Fe(II); Fe(III), Zn^{2+}] and an alkaline pH; (2) phosphorus precipitation is inhibited by ions such as $P_2O_7^{4-}$, Mg^{2+}, CO_3^{2-}, phosphates, and polyvalent carboxylic acids; (3) microorganisms modify wastewater quality with respect to P concentration, cations, pH and they influence P precipitation; (4) P precipitates are amorphous, poorly-crystalline and complex when in biological systems (Jenkins).

A proposal for the formation of an international study group was prepared for submission to IAWPRC on the subject of Biological P Removal. The chairman is D. Jenkins, Berkeley, U.S.A.; the secretary is H. N. S. Weichers, Pretoria, South Africa. The study group plans to operate by correspondence and to meet just prior to the 12th IAWPRC Conference (Jenkins).

An innovative design of secondary clarifiers has been used at the Cape Flats sewage treatment plant, located near Cape Town. The flow is from the perimeter but enters through conduits that extend a substantial distance towards the center of the clarifier in an attempt to avoid short-circuiting over the weir, which is also located around the perimeter. Settled sludge is removed by a rotating suction device. In spite of these changes, the operators stated that the effluent quality was not noticeably better than that obtained with center feed, rim-overflow clarifiers. The Cape Flats plant is a biological nutrient removal facility, however, and its sludge may be more difficult to settle than that of a conventional plant (Randall).

M. R. Roberts and D. A. Kerdachi (South Africa) have accumulated extensive experience with a unique full-scale phosphorus removal plant located at Pinetown Municipality in the Natal, South Africa. This plant has a single aeration tank and is in a soft-water region, yet it has consistently achieved effluent phosphorus concentrations of less than 1 mg/ℓ, corresponding to removals of 92% or more without chemical addition. The high removals were originally observed when the plant was operating at a sludge age of 20 days with total anaerobiosis periods of 10 to 12 hours each day. However, they have also demonstrated high phosphorus removals at sludge ages of 38 and 69 days. The success of the process was attributed to the functioning of two mechanisms which complement one another, chemical removal and excess biological uptake. Under the 20-d sludge age conditions, high phosphate release and excess biological uptake were achieved, but this was gradually shifted to where the primary phosphorus removal mechanics were governed by the equilibrium kinetics of a solid phosphate phase by increasing the sludge age. The process would seem to have a considerable economic advantage over the multiple unit design of the Bardenpho/Phoredox processes, and could be readily adapted to existing conventional plants (Randall).

The combined effects of excess biological phosphorus removal and biologically-mediated phosphorus removal have been studied by E. Arvin of the Technical University of Denmark using a unique system. This system has three or four aeration tanks which are operated in sequence on a batch basis. While one is filling under anaerobic conditions, a second is being aerated and, in a third, the previously aerated sludge is being settled. The fourth can be emptying while the first is filling. Excellent phosphorus removal results have been obtained with this system and Arvin (Department of Sanitary Engineering, Technical University of Denmark, Building 115, DK-2800 Lyngby, DENMARK) has written papers describing the conditions needed to maximize biologically mediated phosphorus precipitation (Randall).

Sludge Treatment and Disposal

An informal discussion with engineers from Japan revealed that sludge treatment and disposal are receiving a great deal of attention because of land shortage and high cost of treatment. In

Tokyo, incineration is the preferred method of disposal. Electrostatic precipitators are employed to prevent air pollution. Composting of sludge and utilization of ash after incineration are also being studied (Kawata).

Quality of Treatment Plant Operation and Performance

Operation and maintenance of sewage treatment plants outside of large municipalities in South Africa is a significant problem. Lack of knowledge of sewage treatment principles is a critical problem. The Institute of Water Pollution Control (South African Branch) offers training courses. Simple plants need to be built, e.g., for the semi-autonomous states such as the Transkei; trickling filters are being designed rather than activated sludge on the logic that a non-operative trickling filter will produce a better effluent than a poorly operated activated sludge plant (Jenkins).

Wastewater Reclamation

The South Africans have been leaders in the development of water reclamation methodology. A very interesting state-of-the-art presentation was given which summarized these efforts. Unfortunately, little in the way of new technology was presented. However, several changes discussed included the trend toward use of biological methodology for removal of nitrogen and phosphorus. At the Windhoek facility, it was noted that the ammonia stripping towers were presently not used (Englande).

The National Institute for Water Research in Pretoria, South Africa, is involved in ambitious studies to improve the conversion of treated municipal sewage into drinking water (Keith).

There is little doubt of the need to develop new water sources in arid sections in the United States. Two main philosophies are being followed. In one, uses of wastewater are directed toward low human contact such as irrigation and ground water recharge either through direct injection or percolation. The other envisions full treatment of wastewater to meet drinking water quality standards and its integration into potable supplies (Olson).

The most cost-effective means of increasing water resources at this time appears to be through the use of treated wastewater for irrigation purposes. This procedure has several advantages over those of direct reuse. The margin of safety is not so critical. The major causes of waterborne disease in the United States today are failures in treatment plant operations, principally in failures in disinfection. Delegates from different countries have different ideas on which strategy to follow. In Israel the decision has been made to restrict reuse to irrigation. This is based on public health considerations and treatment costs. In South Africa, the main thrust is for direct reuse. In the United States various states, have adopted different strategies. In Colorado, the decision for direct reuse for the city of Denver has been made, while California has decided on low contact uses of reclaimed water throughout the state (Olson).

Water reuse is still receiving attention despite the increasing energy cost related to physical-chemical treatment processes. However, a gradual shift has been noted away from adsorption processes such as activated carbon toward groundwater recharge. The latter process allows greater detention times (e.g., months instead of minutes) and greater bed depth and travel distances (e.g., hundreds of meters instead of meters). Although the adsorption capacity is not as great as compared to activated carbon, the longer travel distance compensates for it. When a monitoring well is installed between the recharge well and the pumped well, a regular monitoring program will give timely warning of possible toxic sludges migrating towards the pumped well. Groundwater recharge can be an alternative for the more expensive activated carbon adsorption and should, therefore, be studied in greater detail (DeWalle).

Due to a shortage of water in South Africa, much the same as in the arid southwestern region of the United States, a respectable level of research and engineering activities has been conducted in South Africa. The most impressive studies concern the total reuse of wastewater generated from SASOL II and III synthetic fuel plants and the potable reuse of municipal wastewater effluents. It was observed during the field trips that intensive efforts were made to monitor for both toxic substances and biological parameters, including viruses, to insure the safety of water reuse and the sound disposal of resulting sludges. Although comparable water renovation studies have been conducted in the United States, the level of activity is far from intense. This is especially true if one compares the effective manpower available in South Africa to that in the United States (approximately 1:50). The South Africans have demonstrated innovative use of research results from the United States. An intensive effort in technology transfer is evidenced by the large-scale applications of activated carbon and ion-exchange resins in South African water renovation projects, including the use of carbon and resin regeneration processes. In view of the potential long-term water shortage in many parts of the United States, it is imperative that further long-term research be supported by EPA to fully expand our knowledge in areas of water reuse (Chian).

Ocean Discharge

Even with the great emphasis in water reuse, South Africa is studying and planning ocean discharge of wastewater following minimal treatment (Kawata).

Animal Feed from Algae

The National Institute for Water Research in Pretoria has improved the conversion of algae to animal feeds by advanced technology which shortens the time of processing it and also uses less energy to dry the product (Keith).

Pathogenic Organisms and Viruses

Antibiotic-resistant cholera is becoming endemic throughout most of Africa, and cholera is now being found in waters where it had not been previously, including in South Africa (Bishop).

Parasite viability in sludges following land spreading was of general interest since these organisms are generally more resistant to deactivation than bacteria and viruses. A follow-up session on sludge handling at the post-conference workshop dealt with the problem in more detail. While in England, parasites are not considered a problem in sludges, other countries such as Germany, South Africa and Switzerland are considering limiting the levels of specific parasites in the sludge if it is to be disposed on land for agricultrual purposes (Englande).

The study group on water virology formed by IAWPRC arranged a post-conference seminar on water virology. Various aspects of water virology research needs and priorities were discussed (Roy).

The reappearance of *Vibrio cholerae* along the Southern Coast of the United States is an issue which should be of prominent concern. The origin of these organisms, as those appearing in sea water along the Natal coast South Africa, appear to be from non-point source discharges. *V. cholerae* in many instances appears to be multiplying in fresh water environments and then transported into the marine environment where they are concentrated in shellfish and present a potential health threat. Other new disease agents are also appearing and the origin appears in certain instances to be environmental. *Yersenia entercolictica* as well as *Campylobacter* are accounting for higher incidence of waterborne disease and are suggesting the need for at least disinfection for small water supplies. Solutions are difficult due to cost and maintenance considerations. Further, *Legionella* has focused new concern on cooling waters (Olson).

Chemical pollution of water supplies from hazardous wastes dumps and pesticide use in farming is increasing in the United States. This is particularly a problem with groundwater which prior to the introduction of such pollutants required no treatment before distribution to the public. There is a great need for early warning monitoring systems which can indicate areas where potential problems may occur. This type of early warning system could be extremely useful in taking active measures to prevent the contamination of groundwater (Olson).

Concern was expressed that although bacterial and viral diseases receive wide attention, parasites do not. More effort should be directed toward the factors affecting the longevity of such microbes in the environment. Disinfection studies should be directed to include parasites found in water and wastewater. One delegate was concerned at possible bacterial or viral pathogenic presence in nematodes, and the possibility of their passage to humans via drinking water (Scarpino).

Computer Applications

Discussion with academicians from the United States and other countries revealed that computerized design of environmental engineering processes and units are gaining wider acceptance in teaching and practice (Roy).

Laboratory Techniques

Pretorius at the University of Pretoria, in Pretoria, South Africa, is advocating the use of water as the liquid phase in capillary columns to concentrate and chromatrograph volatile organic pollutants in water samples. He also is working on the development of a "disposable" gas chromatograph. This instrument, cast in a ceramic material and about the size of a large pocket calculator, would consist of a single cast unit containing the injection port, a spiral capillary column and a detector. Because of its low cost, he thinks it should be cheaper to replace it with a new one rather than try to fix it or recondition the column. If a disposable gas chromatograph can really be sold for the approximate cost of the capillary columns, then it might be a viable product. It certainly would add to the convenience of on-site analyses and, if mass produced, it would make gas chromatographic analyses within everyone's capability (Keith).

Toxic and Hazardous Materials

In view of increasing awareness and concern related to the presence of toxic substances in surface and groundwater sources, and the anticipated capital investment and operating costs that may be required for control of these substances, additional research is needed to evaluate presently available treatment technology in reducing concentrations of toxic materials in wastewater. Additional research is needed to develop low cost treatment processes (Rohlich).

Much concern was voiced over toxicity evaluations for potable water and wastewater effluent. Delegates agreed that a battery of testing is required for toxicity characterization. Particular significance was given to the need for a chronic toxicity testing protocol to isolate those chemical constituents which potentially could cause health effects. There was consensus over the fact that methodology is in a state of infancy and, for the most part, insufficient to fully assess impacts on public health (Englande).

There appears to be a growing recognition of the need to supplement chemical evaluation of potable water supplies with toxicological testing, both for conventional sources and reuse systems. At the same time, there seems to be considerable uncertainty as to the significance of the toxicological test results and their interpretation in assessing the human risks from exposure to such water. Nevertheless, there are increased efforts in bio-testing the complex mixtures found in these waters, even when they are poorly characterized as to chemical content (Andelman).

The question raised most frequently by delegates from the United States was the validity of certain standards in drinking water for compounds which are carcinogenic or potentially carcinogenic as evidenced by mutagenicity. Research should be directed not only at technical solutions but also at risk-benefit assessment which can be related to some concrete concepts. The very idea of what is acceptable risk was debated by many delegates usually expressing the philosophy of his or her own scientific background. However, to develop meaningful standards and to manage water pollution, a consensus is seriously needed. If one could be achieved, then a better desire for compliance might exist for all agencies concerned (Olson).

The question is complex, as can be pointed out by the disagreement on the need for disinfection of effluents or the level of disinfection acceptable in drinking water supplies. The difference in attitude between the United States and most countries in Europe is great. Yet, little discussion ever seems to center on the meaning of how much disinfection is necessary versus how much is beneficial for public health. Indeed, I believe this would lead to very lively discussions among microbiologists throughout the world. Yet, this bears directly on the problem of trihalomethanes. Thus, the microbiologist and the chemist now more than ever need to address such questions in a common forum. The current need for such a forum is obvious (Olson).

Inorganic hazardous wastes are routinely disposed of by landfilling after solidification/stabilization in the United Kingdom. Several delegates reported that this has resulted in no or only minimal impact on the environment (Bishop).

Several participants expressed the need for additional information on health effects of low level concentrations of toxic substances in water, and the need for low-risk analyses (Rohlich).

One of the major purposes for many attending the conference was to obtain further knowledge on the extent of employment, safety, and monitoring of potentially hazardous materials used in agriculture (e.g., sewage amendment of soil) and feed/food (e.g., algal protein concentrate). Another was to gain knowledge of the extent of, or recent estimates of, the extent of the contamination of food organisms with anthropogenic toxicants, both organic and inorganic. There was interest and concern in both of these problems. There appeared to be increasing interest, for example, in the use of sewage-derived materials for soil amendment, and the production of highly proteinaceous substances for feed/food purposes from organisms (such as algae) grown on toxically contaminated substrates such as wastewater. However, there did not appear to be concern of comparable magnitude for the toxic potential of such practices. Indeed, research focused on this problem appears to have received minimal support worldwide. Without thorough knowledge of the toxic potential of these practices, their continued implementation may be analogous to the proverbial timebomb (Massaro).

Nitrates

Prince (France) indicated that the city of Paris is attempting biological denitrification of drinking water facilities. Apparently, the raw water source for Paris contains nitrates in excess of 200 mg/ℓ, thus, a need for stable techniques for denitrification of drinking water facilities exists (Neufeld).

Ozonation of Wastewaters

Considerable interest was expressed in the area of ozonation of effluents for disinfection purposes, and for advanced wastewater treatment purposes. Interest was expressed on the part of several South Africans in the area of ozonation for modification of molecular structures from nonbiodegradable residuals to biologically decomposable substances. Such research may have great impact in the United States in the development of BAT regulations for the petrochemical and organic chemicals industries (Neufeld).

Use of Mathematical Models

The use of models in decision making for solving United States water pollution control problems could be enhanced by requiring that confidence limits be stated along with model prediction; that the appropriate model be used (i.e., not too complex or too simple); that the user agency be included in model development; and that adequate model validation be proven. It is not obvious how this can be done, but tightening the requirements of pollution control agencies, the obvious one being EPA, would help. Although this seems contradictory to the current mood for less regulation, it will be necessary if modeling and the profession are to be credible in the future (Roberts).

More research in the areas of "black box" models with real-time data would be desirable. It seems that presently these models are more used in Europe than in the United States. Research in modeling the chemistry of anaerobic estuaries was also suggested. Finally, establishment of a clearing house would aid in avoiding duplication of effort and could provide a common pool of information. A workshop on modeling at the next international conference would be highly desirable (Roberts).

Environmental Control Effort

Out of several informal conversations and discussions, concern was expressed about the retrenchment or scaledown of United States water pollution research activities. The belief was that the United States is the leader, and if it falters, so will others. It was obvious that they would look to the United States and EPA, in particular, for leadership in pollution control (Scarpino).

State-of-the-Art Consensus Papers

Extensive discussion takes place at each conference concerning the interpretation and application of research discoveries to practice. Many delegates differ in their experience with regard to how and when to make certain research applications. Different research engineers and research scientists draw different conclusions from the same set of facts. If those who create the facts differ in their interpretation, consider the problems of the consultant who tries to apply them in his practice. Alexander (South Africa) commented that, in his opinion, the biggest gap in technology transfer is the lack of "comprehensive state-of-the-art papers" (Baumann).

Professional societies, government regulatory agencies, consulting engineers, and educators could provide a significant improvement in technology transfer if they would develop "state-of the art papers" on water and wastewater treatment processes and models on which there is common agreement. These could be developed and published in the same manner as *Standard Methods for Examination of Water and Wastewater* is developed. The development of example problems showing all calculations involved in the interpretation and application of processes (together with sensitivity calculations for expected variations in assumed constants and coefficients) would aid in bringing process fundamentals to the engineer, scientist or operator who has to make it work (Baumann).

APPENDICES

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APPENDIX I

11TH CONFERENCE
OF THE
INTERNATIONAL ASSOCIATION ON
WATER POLLUTION RESEARCH
(IAWPR)

CIVIC CENTRE
CAPE TOWN

29 March – 2 April 1982

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SCHEDULE OF EVENTS

NOTES:

1. The programme for accompanying persons is not included here, but is given on p 19
2. A bus service will be provided to and from hotels which are not within easy walking distance from the various venues. The bus timetable is given on p 22

SUNDAY 28 MARCH

09h30	Depart from Civic Centre on tours PCT 4 (Cape Point) and PCT 5 (Hermanus)
15h00	Depart from Civic Centre on tour PCT 3 (Orientation)
16h00–18h30	Registration (mezzanine level, Civic Centre)
19h00–20h30	Meet and greet reception, hosted by the Water Research Commission, in the Venetian Room, Heerengracht Hotel

MONDAY 29 MARCH

07h30–08h30	Registration (mezzanine level, Civic Centre)
08h45	Delegates to take up seats in the Nico Malan Theatre (adjacent to Civic Centre) for Opening Ceremony
09h00–10h30	Opening Ceremony in Nico Malan Theatre (for programme see p 5)
10h30–11h00	Tea/coffee at Civic Centre
11h00–11h45	Poster presentations* Civic Centre (mezzanine level)
11h45–17h35	Technical sessions, Civic Centre
19h00–20h15	Civic reception, Civic Centre concourse

TUESDAY 30 MARCH

08h30–16h35	Technical sessions, Civic Centre
16h40	Buses depart from Civic Centre for braaivleis (barbecue) at Bien Donné experimental farm near Paarl

WEDNESDAY 31 MARCH

08h30	Buses depart from Civic Centre for technical excursions T1 to T6 (see p 10)
Evening	Free or Spend the evening with a South African family. (Overseas delegates only**)

THURSDAY 1 APRIL

09h00–17h35	Technical sessions. Civic Centre
19h30–23h00	Conference banquet at Good Hope Centre

FRIDAY 2 APRIL

09h00–17h35	Technical sessions. Civic Centre
17h35–19h00	Cheese and wine farewell function (Civic Centre)

* Additional periods for poster presentations are listed in the technical programme

** The Cape Town Overseas Hospitality Club extends a friendly invitation to all overseas delegates to spend an evening with a South African family. Overseas delegates interested in this invitation should contact the Registration Desk for further particulars on MONDAY 29 MARCH 1982.

OPENING CEREMONY

(NICO MALAN THEATRE)

MASTER OF CEREMONIES: Mr P E Odendaal, Chairman Conference Organizing Committee

MUSIC: Nicola Petrovic Trio

08h45	Delegates to take up seats
	MUSICAL INTERLUDE
09h00–10h30	Opening ceremony

PROGRAMME

Welcoming address: His Worship the Mayor of Cape Town: Alderman M J van Zyl

Welcoming representatives of individual countries: Master of Ceremonies

Opening Address: Dr C F Garbers, President of the Council for Scientific and Industrial Research

Address by Conference President: Dr G J Stander

MUSICAL INTERLUDE

Address by IAWPR President: Prof R S Engelbrecht

Conferring IAWPR honorary membership on Prof. S Iwai, Japan

Announcements

TECHNICAL PROGRAMME

(INCLUDING TECHNICAL VISITS)

Technical sessions will be held at the Civic Centre in the following three halls:

Hall A: Ground floor (Small Theatre)

Hall B: Ground floor (Podium Hall)

Hall C: Mezzanine level (beyond registration and poster area)

MONDAY 29 MARCH

10h30–11h00 Tea coffee at Civic Centre. to be served immediately after the Opening Ceremony

11h00–11h45 Posters (exhibited in area adjacent to registration on the mezzanine level)

	HALL A	HALL B	HALL C
	Chairman: E C Reed (UK)	**Chairman:** C F Seyfried (FRG)	**Chairman:** W J Weber (USA)
	Recorder: J Sidwick(UK)	**Recorder:** P Wolf (FRG)	**Recorder:** L D Lash (USA)
11h45–12h30	P1 The Effect of Submarine Wastewater Discharge on the Bacterial Quality of Surf Waters – *D J Livingstone (SA)*	P2 The Effect of Aeration Basin Configuration on Activated Sludge Bulking at Low Organic Loading – *S E Lee. B L Koopman. D Jenkins. R F Lewis (USA)*	P3 Development of Water Reclamation Technology in South Africa – *A J Clayton. L R J van Vuuren. B Roux (SA)*
	Invited Discusser: B H Olson (USA)	**Invited Discusser:** W C Boyle (USA)	**Invited Discusser:** R D Heaton (USA)

12h30–14h00 LUNCH

13h15–14h00 PRESENTATION OF POSTERS S1 – S20

	Chairman: E C Reed	**Chairman:** C F Seyfried (FRG)	**Chairman:** W J Weber (USA)
	Recorder: J Sidwick (UK)	**Recorder:** P Wolf (FRG)	**Recorder:** L D Lash (USA)
14h00–14h45	P4 Surface Dilution of Round Negative Buoyant Jets – A Comparison with Other Jets – *G Noutsopoulos. J Demetriou (Greece)*	P5 Obtaining Secondary Treatment with RBC Underflow Clarifiers – *I L Bogert (USA)*	P6 Removal of Potential Carcinogens and Toxicants by Treatment Systems for Direct and Indirect Reuse of Wastewater Evaluated by means of a Hamster Cell Culture Assay – *R Kfir. O W Prozesky (SA)*
	Invited Discusser:	**Invited Discusser:** A H Molof (USA)	**Invited Discusser:** J B Andelman (USA)
14h50–15h35	P7 The Distribution and Significance of Toxic Metals in Sharks from the Natal Coast. South Africa – *R J Watling. H R Watling. R C Stanton. T P McClurg. E M Engelbrecht (SA)*	P8 Optimization of Nitrogen Removal in the Single Sludge Activated Sludge Process – *A C van Haandel. P L Dold. G v R Marais (SA)*	P9 Organic Micropollution of Potable Water Supplies – Indirect versus Direct Reuse – *J F J van Rensburg. S J Theron. A J Hassett. P G van Rossum (SA)*
	Invited Discusser: E J Massaro (USA)	**Invited Discusser:** Y Matsuo (Japan)	**Invited Discusser:** S D Walle (USA)

15h35–16h00 REFRESHMENTS PRESENTATION OF POSTERS S21 – S40

	Chairman: E J Hall (SA)	**Chairman:** L Coin (France)	**Chairman:** A Van Haute (Belgium)
	Recorder: L R J Van Vuuren (SA)	**Recorder:** C Gomella (France)	**Recorder:** W Maschelein (Belgium)
16h00–16h45	P10 Baseline Studies and Continuous Monitoring for a Shallow Tropical Bay Receiving Nickel Refinery Effluent – *J E Carey. M A Pettit. W S Rooney. T L Judell (Australia)*	P11 Fate of Heavy Metals and Potential for Clinker Formation during Pilot Scale incineration of Municipal Sludge – *H W Campbell. P J Crescuolo. T R Bridle (Canada)*	P12 The Economic Impact on an urban Industrial Complex of Mineral Pollution in the Water Supply – A Case Study – *J J C Heynike. S F McCulloch (SA)*
	Invited Discusser: R B Clark (UK)	**Invited Discusser:** A Gerber (SA)	**Invited Discusser:** C Herold (SA)
16h50–17h35	P13 Influence of Discharges from Storage Reservoirs on the Tastes and Odours Appearing in the Seine and Marne Rivers – *M Rizet. J Mouchet (France)*	P14 The Use of Rheology for Sludge Characterization – *H W Campbell. P J Crescuolo (Canada)*	P15 Limnological Effects of the Elimination of Phosphorous from the Wahnbach Reservoir – *H Bernhardt. J Clasen (FRG)*
	Invited Discusser: R Gehr (Canada)	**Invited Discusser:** Marchandise (France)	**Invited Discusser:** C Basalo (France)

TUESDAY 30 MARCH

	HALL A	HALL B	HALL C
	Chairman: W A Bridgeo (Canada) **Recorder:** R Gehr (Canada)	**Chairman:** J Matsumoto (Japan) **Recorder:** Y Walanabe (Japan)	**STATE-OF-THE-ART** THEME 1: THE USE OF MATHEMATICAL MODELS **Convener:** A Gerber (SA) **Recorder:** C Basalo (France) (a) Review and Background – *A Gerber (SA)* (b) Application to Estuarine & Coastal Waters – *A L Gameson (UK)* (c) Application to River & Underground Waters – *J Dinctx (Belgium)* (d) The Use of Modelling in Management Decisions – *P A Krenkel & T O Barnwell (USA)* (e) Mathematical Modelling of Estuaries and Coastal Waters – *A James (UK)* DISCUSSION **Invited Discusser:** R Briggs (UK)
08h30–09h15	P16 New Methods for Analysing Water Pollutants – *L H Keith, R C Hall, R C Hanisch, R G Landolt, J E Henderson (USA)* **Invited Discusser:** J F J Van Rensburg (SA)	P17 Slow Sand Filtration for Cercarial Control in North Cameroon Village Water Supply – *K Kawata (USA)* **Invited Discusser:** P Williams (SA)	
09h20–10h05	P18 Simultaneous in situ Determination of Dissolved Gases by Gas Chromatography: II Oxygen and Nitrogen in Activated Sludge Process Streams – *T Bistad, E N Lightfoot (Norway, USA)* **Invited Discusser:** P G Van Rossum (SA)	P19 Characterization of Fouling Potential for Pressure-Driven Membrane Processes: A New Simulated Flow Cell – *R H Reed, G Belfort (USA)* **Invited Discusser:** E S K Chian (USA)	
10h05–10h30	REFRESHMENTS PRESENTATION OF POSTERS S1 – S20		
	Chairman: M Chaudhuri (India) **Recorder:** P Coombs (SA)	**Chairman:** W H J Hattingh (SA) **Recorder:** E Ottman (FRG)	**STATE-OF-THE-ART** THEME 1: THE USE OF MATHEMATICAL MODELS CONTINUATION
10h30–11h15	P20 Nutrients Removal and Recovery in a Two-Stage High-Rate Algal Wastewater Treatment System – *G Shelef, U Azov, R Moraine (Israel)* **Invited Discusser:** D Albrecht (FRG)	P21 Desalination by Continuous Ion Exchange Based on Thermally Regenerable Magnetic Microresins – *B A Bolto, E A Swinton (Australia)* **Invited Discusser:** A D Carr (SA)	
11h20–12h05	P22 Operational Management of Pollution Incidents – The Thames Way, UK – *E C Reed, M C Dart (UK)* **Invited Discusser:** P R Philip (France)	P23 Continuous Counter-current Ion Exchange for Desalination and Tertiary Treatment of Effluents and Other Brackish Waters – *B A Hendry (SA)* **Invited Discusser:** M J Semmens (USA)	
12h05–13h00	LUNCH		
12h35–13h00	PRESENTATION OF POSTERS S21 – S40		
	Chairman: D H Newsome (UK) **Recorder:** G Eden (UK)	**Chairman:** H Biersch (SA) **Recorder:** J R Simpson (UK)	**STATE-OF-THE-ART** THEME 2: OIL POLLUTION IN MARINE AND FRESHWATER ENVIRONMENTS **Convener:** N King (UK) **Recorder:** D C Macleod (SA) (a) Review and Background – *N King (UK)* (b) Legal & Administrative Control – *A D Read (UK)* (c) Sources of Oil Pollution – *F G Payne & M T Westaway (UK)* (d) Economic Aspects of Oil Pollution – *H P Luhr (FRG)* (e) Effects of Oil Pollution and Research Needs – *R B Clark (UK)* (f) Methods of Treatment – *F Berne (France)* DISCUSSION
13h00–13h45	P24 Viability and Adaptability of E Coli and Enterococcus Group to Salt Water with High Concentration of Sodium Chloride – *T Omura, M Onuma, Y Hashimoto (Japan)* **Invited Discusser:**	P25 On the Mass-Transfer Characteristics Within Microbial Systems – *M Onuma, T Omura (Japan)* **Invited Discusser:** W J Grenney (USA)	
13h50–14h35	P26 Chlorine-Resistance of Coliform-tested Bacteria Isolated from Raw and Treated Sewage Effluents – *L Y C Leong, D Otsaka, H F Ridgway, B H Olson (USA)* **Invited Discusser:** J Vial (France)	P27 The Scale-up and Limitation of Physical Oxygen Transfer in Rotating Biological Contactors – *B J Kim, A H Molof (USA)* **Invited Discusser:** P L Bishop (USA)	
14h35–15h00	REFRESHMENTS PRESENTATION OF POSTERS S21 – S40		
	Chairman: H Leskela (Finland) **Recorder:** P Lehmusluoto (Finland)	**Chairman:** J E Lind (Sweden) **Recorder:** B Encsson (Sweden)	**STATE-OF-THE-ART** THEME 2: OIL POLLUTION IN MARINE AND FRESHWATER ENVIRONMENTS CONTINUATION
15h00–15h45	P28 Ozonation of Aromatic Compounds pH-Dependence – *E Gilbert (FRG)* **Invited Discusser:** M Schalekamp (Switz.)	P29 Application of the Marais-Ekama Activated Sludge Model to Large Plants – *H A Nicholls (SA)* **Invited Discusser:** W W Eckenfelder (USA)	
15h50–16h35	P30 Presence of Phenolic Compounds in Sewage, Effluent and Sludge from Municipal Sewage Treatment Plants – *F B de Walle, D A Kalman, D Russell, D Norman, S K Chian (USA)* **Invited Discusser:** D W Osbom (SA)	P31 A Mathematical Model of Biological Purification in Aerated Activated Carbon Biofilters – *G Martin, A Y le Roux, P Schulof (France)* **Invited Discusser:** G Eden (UK)	

WEDNESDAY 31 MARCH

FULL DAY TECHNICAL VISITS

NOTES

1. A choice of six options, T1 to T6 had been presented to delegates and each delegate had indicated his first three choices in order of priority on the registration form. In allocating places on the tours, delegates' first choices have as far as possible been adhered to. As certain of the tours have been oversubscribed, however, some delegates have been placed on tours of their second or third choice.

2. **IMPORTANT:** Symbols ranging from T1 to T6 will appear on the name tag which each delegate will receive on registration. These numbers will correspond with the tours on which delegates have been placed and they must board a bus with the corresponding number when the tour buses depart from the Civic Centre.

3. A booklet providing information and technical details of the various installations to be covered by all six tours, T1 to T6, will be included in the material which delegates will receive on registration. REMEMBER TO BRING THIS ALONG ON THE TOURS.

4. Boxed lunches will be provided on the buses at no additional cost to participants.

T1 PAARL SEWAGE WORKS

08h00	Pick up at hotels
08h30	Depart Civic Centre
09h45	Arrive Paarl Sewage Works for plant visit
11h30	Travel to Cape Flats, lunch on bus
12h30	Visit Cape Flats Sewage Works and experimental reclamation plant
14h30	Return to hotels via scenic route (about 2 hours)

T2 STEENBRAS WATER TREATMENT PLANT

08h00	Pick up at hotels
08h30	Depart Civic Centre and travel via scenic route to Gordons Bay
11h15	Visit Steenbras Water Treatment Plant
12h05	Lunch at Steenbras Dam
13h45	Travel to Cape Flats
14h30	Visit Cape Flats Sewage Works and experimental reclamation plant
16h30	Return to hotels (about 40 min.)

T3 BELLVILLE SEWAGE WORKS

08h00	Pick up at hotels
08h30	Depart Civic Centre and travel via scenic route
10h30	Visit Cape Flats Sewage Works and experimental reclamation plant
12h30	Lunch at Zeekoevlei
13h30	Depart for Bellville Sewage Works
14h15	Arrive Bellville Sewage Works for plant visit
16h15	Return to hotels (about 40 min)

T4 INSTITUTE OF SEA FISHERIES

08h00	Pick up at hotels
08h30	Depart Civic Centre
09h15	Arrive Cape Flats for visit to Sewage Works and experimental reclamation plant
10h30	Travel via scenic route with stop for lunch
14h00	Visit Institute of Sea Fisheries (Sea Point) and Research Vessel (Cape Town Harbour)
16h30	Return to hotels (about 15 minutes)

T5 UNIVERSITY OF CAPE TOWN

08h00	Pick up at hotels
08h30	Depart Civic Centre
09h15	Arrive Cape Flats for visit to sewage works and experimental reclamation plant
10h30	Travel via scenic route with stop for lunch
14h00	Visit University (Departments of Civil and Chemical Engineering)
16h00	Return to hotels (about 20 min.)

T6 KOEBERG-MILNERTON

08h00	Pick up at hotels
08h30	Depart Civic Centre
09h00	Visit Koeberg Nuclear Power Station
10h15	Travel to Milnerton
10h30	Visit Milnerton Sewage Works
11h45	Travel to Cape Flats with lunch on bus
12h30	Visit Cape Flats Sewage Works and experimental reclamation plant
14h30	Return to hotels via scenic route (about 2 hours)

	HALL A	HALL B	HALL C
	Chairman: A M Wachs (Israel) **Recorder:** E Idelovitch (Israel)	**Chairman:** T L Judell (Australia) **Recorder:** W Raper (Australia)	**STATE-OF-THE-ART** THEME 3: THE ECONOMICS OF WATER POLLUTION CONTROL & RESEARCH **Convener:** G Rincke (FRG) **Recorder:** K Pöppinghaus (FRG) (a) Review and Background – *G Rincke (FRG)* (b) Funding Water Pollution Control in South Africa – *J A Lusher (SA)* (c) Funding Water Pollution Research – *G Rohlich (USA)* (d) Balancing Benefits & Expenditure – *C Lefrou (France)* DISCUSSION **Invited Discusser:** R A Canham (USA)
09h00–09h45	P32 An Appraisal of the Performance of a Continuous Automatic Fish Biomonitoring system at an Industrial Site – *W S G Morgan. P C Kuhn. B Allais. G Walls (SA)* **Invited Discusser:** T Yoshida (Japan)	P33 Granular Activated Carbon and Preozonated Granular Activated Carbon Treatment for Biologically and Physically-Chemically Treated Wastewater Effluents – *A Netzer. J L McNutt (USA)* **Invited Discusser:** W J Weber (USA)	
09h50–10h35	P34 Examination of a Drinking-water Supply for Mutagenicity – *P G van Rossum. J M Willemse. C Hiner. L Alexander (SA)* **Invited Discusser:**	P35 The Nature of the Reactions Between Chlorine and Purine and Pyrimidine Bases: Products & Kinetics – *J P Gould. T R Hay (USA)* **Invited Discusser:** C W Randall (USA)	
10h35–11h00	REFRESHMENTS PRESENTATION OF POSTERS S21 – S40		
	Chairman: A H Munoz (Spain) **Recorder:** F M Bardaji (Spain)	**Chairman:** H I Shuval (Israel) **Recorder:** M Patrick (N.Zealand)	**STATE-OF-THE-ART** THEME 3: THE ECONOMICS OF WATER POLLUTION CONTROL & RESEARCH CONTINUATION
11h00–11h45	P36 Depositional Process of Fine Sediments – *T Kusuda. T Umita. K Koga. H Yorozu. Y Awaya (Japan)* **Invited Discusser:** C Davis (SA)	P37 The Fate of Some Metal Species: Lead. Cadmium. Zinc in Surface Water During Biological Sand Filtration – Effects of Preozonation – *F Erb. D Delabre. J C L Hopitault. A Philippo. P Thomas. A Brice (France)* **Invited Discusser:**	
11h50–12h35	P38 Nutrients and Algal Growth in an Impounded River. Consequences for its Oxygen Balance and Nutrient Control Strategy – *K R Imhoff. D R Albrecht (FRG)* **Invited Discusser:** Casteignau (France)	P39 A New Configuration of the High-Lime Process with Sludge Recirculation for Magnesium Recycling – *E Idelovitch. A M Wachs (Israel)* **Invited Discusser:** B A Bell (USA)	
12h35–14h00	LUNCH		
13h15 – 14h00	PRESENTATION OF POSTERS S1 – S20		
	Chairman: T Bilstad (Norway) **Recorder:** P H Jones (Canada)	**Chairman:** H W Campbell (Canada) **Recorder:** A S Almeida (Brazil)	**STATE-OF-THE-ART** THEME 4: TECHNOLOGY TRANSFER **Convener:** S H Eberle (FRG) **Recorder:** M R Henzen (SA) (a) Review and Background – *S H Eberle (FRG)* (b) Scale-Up Problems – *J Sidwick (UK)* (c) The Role of Consultants – *W Eckenfelder (USA)* (d) Involving Practitioners in Research – *P E Odendaal (SA)* (e) Packaging of Information – *M J Pieterse (SA)* (f) Role of Equipment Manufacturers – *J Bernard (France)* DISCUSSION **Invited Discusser:** W Von der Emde (Austria)
14h00–14h45	P40 Impact of Nuclear Power Plants of the PWR-type on River Quality – *W J Masschelein. J Genot (Belgium)* **Invited Discusser:** L Henry (Australia)	P41 An Integrated Low Cost System for Treatment of Potato Processing Wastewater Incorporating Anaerobic Fermentation and Phosphorus Removal – *J G Parker. B J Lyons. C D Parker (Australia)* **Invited Discusser:** B Ericsson (Sweden)	
14h50–15h35	P42 Fractional Composition of Phosphorus Forms in Sediments Related to Release – *H Furumai. S Ohgaki (Japan)* **Invited Discusser:** C A Bruwer (SA)	P43 The Adsorption Behaviour of Cationic Polyelectrolytes in Dissolved Air Flotation – *R Gehr. J G Henry (Canada)* **Invited Discusser:** B M Van Vliet (SA)	
15h35–16h00	REFRESHMENTS PRESENTATION OF POSTERS S1 – S20		
	Chairman: K R Imhoff (FRG) **Recorder:** H P Luhr (FRG)	**Chairman:** R Chalmers (UK) **Recorder:** J G Parker (Australia)	**STATE-OF-THE-ART** THEME 4: TECHNOLOGY TRANSFER CONTINUATION
16h00–16h45	P44 The Influence of Sediment Water Interactions in an Impoundment on Downstream Water Quality – *T J Grizzard. C W Randall. E M Jennelle (USA)* **Invited Discusser:** W H J Hattingh (SA)	P45 The Performance of an Ultrafiltration Pilot-plant for the Closed Loop Recycling of Textile Desizing Effluents – *C A Buckley. R B Townsend. R Groves (SA)* **Invited Discusser:** A Netzer (USA)	
16h50–17h35	P46 River-Basin Planning for Control of Nitrate Pollution – *C S Sinnott. D G Jameson (UK)* **Invited Discusser:** H C Preul (USA)	P47 Leaching Characteristics of Industrial Metal Finishing Wastewater Treatment Plant Solids – T H Goodgame. P W Barnett (USA) **Invited Discusser:** J W Funke (SA)	

FRIDAY 2 APRIL

	HALL A	HALL B	HALL C
	Chairman: I Hespanhol (Spain) **Recorder:** R Ludwig (Brazil)	**Chairman:** W Von der Emde (Austria) **Recorder:** H Kross (Austria)	STATE-OF-THE-ART THEME 5 WATER POLLUTION CONTROL IN DEVELOPING AREAS **Convener:** P H Jones (Canada) **Recorder:** (a) Review and Background – *P H Jones (Canada)* (b) Institutional Arrangements and Funding – *B Hawerman (Sweden)* (c) Training and Education – *K Poppinghaus (FRG)* (d) Low Cost Technology – *G G Cillie (SA)* (e) Problems and Needs – *J R Simpson (UK)* DISCUSSION **Invited Discusser:** J E Lind (Sweden)
09h00–09h45	P48 Virus Removal by Filtration – *N Sriramulu, M Chaudhuri (India)* **Invited Discusser:** L Y C Leong (USA)	P49 Aerobic Thermophilic Stabilization of Sludge Versus Anaerobic Digestion and Other Kinds of Sludge Treatment at Middle-sized Plants with Respect to Power Conservation and Economy – *P Wolf (FRG)* **Invited Discusser:** J Bernard (France)	
09h50–10h35	P50 Enterovirus Concentration using Automated Hollow Fiber Ultrafiltration – *G Belfort, A Paluszek, L S Sturman (USA)* **Invited Discusser:** O J Sproul (USA)	P51 Simultaneous Pasteurisation-Digestion (SPD-Process) – *G Kugel (FRG)* **Invited Discusser:** S Baines (UK)	
10h35–11h00	REFRESHMENTS PRESENTATION OF POSTERS S1 – S40		
	Chairman: G Belfort (USA) **Recorder:** J F J Van Rensburg (SA)	**Chairman:** J P Matthews (UK) **Recorder:** C S Sinnott (UK)	STATE-OF-THE-ART THEME 5: WATER POLLUTION CONTROL IN DEVELOPING AREAS CONTINUATION
11h00–11h45	P52 A Comparative Study of Methods for Concentration of Human Enteroviruses – *M T Martins, E Marques, L A Soares (Brazil)* **Invited Discusser:** E Nupen (SA)	P53 Inhibition Modelling in Anaerobic Digestion – *A C Duarte, G K Anderson (Portugal, UK)* **Invited Discusser:** G v R Marais (SA)	
11h50–12h35	P54 A New Large Scale Technique for Quantitative Recovery of Enteroviruses by Adsorption on Suspended Glass Powder. Application to Surface and Drinking Waters of the Paris Area – *P H Vilagines, B Sarrets, C Danglot, R Vilagines (France)* **Invited Discusser:** D Roy (USA)	P55 Process Integration in Sludge Management – *R I Dick, D L Simmons, Y Hasit (USA)* **Invited Discusser:** G Kugel (FRG)	
12h35–14h00	LUNCH POSTERS TO BE DISMANTLED		
	Chairman: D W Osborn (SA) **Recorder:** W O K Grabow (SA)	**Chairman:** P G J Meiring (SA) **Recorder:** R Gehr (Canada)	STATE-OF-THE-ART THEME 6 WATER RECYCLING **Convener:** K D Linstedt (USA) **Recorder:** E R Bauman (USA) (a) Review and background – *K D Linstedt (USA)* (b) Water Recycling Schemes – *R D Heaton (USA)* (c) Industrial Applications – *D R Albrecht & K Imhoff (FRG)* (d) Domestic and Agricultural Applications – *C F Schutte (SA)* (e) Health Risks – *H I Shuval (Israel)* (f) Research Needs – *A L Downing & G Eden (UK)* DISCUSSION **Invited Discusser:** R Chalmers (UK)
14h00–14h45	P56 Ozone as a Sterilising Agent, its Advantages and Disadvantages in the Treatment of Water – *M Schalekamp (Switzerland)* **Invited Discusser:** J van Leeuwen (SA)	P57 Elements of the Inhibition of Nitrifying Bacteria – *G Martin, Y Richard (France)* **Invited Discusser:** D Jenkins (USA)	
14h50–15h35	P58 The Mechanism of Ozone Inactivation of Water Borne Viruses – *O J Sproul, R M Pfister, C K Kim (USA, Korea)* **Invited Discusser:** J P Gould (USA)	P59 Biological Nitrification in an Up-flow Fixed Bed Reactor (UFFBR) – *G M Faup, A Leprince, M Pannier (France)* **Invited Discusser:** R D Neufeld (USA)	
15h35–16h00	**REFRESHMENTS**		
	Chairman: J Bernard (France) **Recorder:** J Vila (France)	**Chairman:** P Harremoës (Denmark) **Recorder:** P L Doid (SA)	STATE-OF-THE-ART THEME 6: WATER RECYCLING CONTINUATION
16h00–16h45	P60 Predicted Changes in Water Quality after Elimination of Storm Runoff into the Urban Lake and Canals of Hamburg – *H Caspers (FRG)* **Invited Discusser:** C W Randall (USA)	P61 Simulation of Nitrification and its Dynamics in a Rotating Biological Contactor – *Y Watanabe, H E Bravo, K Nishidome (Thailand, Japan)* **Invited Discusser:** C W Saunders (USA)	
16h50–17h35	P62 Quality and Quantity of Stormwater Runoff from a Commercial Land-Use Catchment in Natal, South Africa – *D E Simpson, P H Kemp (SA)* **Invited Discusser:** J R Simpson (SA)	P63 Effect of Denitrification on the pH in Biofilms – *E Arvin, G H Kristensen (Denmark)* **Invited Discusser:** Cornier (France)	

SPECIAL NOTE

TIMETABLE FOR TECHNICAL PROGRAMME ON TUESDAY 30 MARCH

Please note that the timetable for the technical programme on Tuesday 30 March had to be adapted in order to allow an early afternoon departure for the Bien Donné function.

The first session will commence at 08h30 instead of 09h00 and the lunch period will be 55 minutes instead of 85 minutes. The last session will therefore conclude at 16h35 instead of 17h35. Please also note the amended times for briefing sessions.

BRIEFING SESSIONS FOR AUTHORS, SESSION CHAIRMEN, RECORDERS AND INVITED DISCUSSERS

Briefing sessions for authors, session chairmen, recorders and invited discussers, will be held each day in the specific halls in which they will present their papers or do duty on that day. The briefing periods will commence at the following times:

Monday 29 March : 11h15
Tuesday 30 March : 08h00 and 12h30
Thursday 1 April : 08h30 and 13h30
Friday 2 April : 08h30 and 13h30

The persons who will lead the briefing sessions in the three halls are:

HALL A : Phil Coombs
HALL B : Keith McCusker
HALL C : Piet Odendaal

IMPORTANT NOTE FOR AUTHORS: SLIDES FOR PROJECTION

1. Authors should hand their slides to the technician on duty in the hall where they will present their papers **immediately before the start of the session during which they will make their presentation.** Authors should collect their slides and check them at the end of the session.
2. A **slide viewing room** will be available next to the Podium Hall (Hall B) for authors who wish to screen or examine their slides beforehand.

POSTER PRESENTATIONS

Authors of posters presentations will be on duty at the times indicated in the technical programme. In addition, special appointments can be made with authors on appointment pads which will be available on each author's table.

The following posters will be exhibited on the mezzanine level in the area adjacent to registration:

S1. Removal of Pesticides and Herbicides by means of Adsorption on Activated Carbon.
D.V. Heroes (Belgium)

S2. Computer Control in a Sewage Plant, Methods and Experience.
C.P. Kuznia (FRG)

S3. Adsorption and Biodegradation of Linear Alkylbenzene Sulfonates (LAS) by Activated Sludge.
K. Yoshimura, A. Nakae (Japan)

S4. The Application of Pre-Treatment Procedures to Limit Membrane Fouling in Reverse Osmösis Reclamation of Secondary Sewage Effluents.
H.A. de Villiers, G.R. Botha, M.H. Wright (South Africa)

S5. Flotation as the Final Clarification Step in Wastewater Treatment and its Influence on the Oxygen Balance of Receiving Waters.
K.P. Kiefhaber, U. Neis, J. Weber (FRG)

S6. The Disposal of Sewage Sludge by Land Spreading.
J.H. Nell, J.F.P. Engelbrecht (South Africa)

S7. Total Mercury Concentrations in some Species of South African Commercial Marine Fish.
J. Henry (South Africa)

S8. Toxicity Testing of South African Oil-Spill Dispersants.
A. Moldan, P. Chapman (South Africa)

S9. Effect of Oil on Reproductive Capacity of *Callianassa Kraussi*.
Lynn F. Jackson (South Africa)

S10. The Use of Ultraviolet Absorption in the Measurement of Fish-Factory Pollution.
P. Chapman (South Africa)

S11. The Survival of Bacterial Indicators in Lysimeters and Landfills.
J.A. Donnelly, P.V. Scarpino, D. Brunner (USA)

S12. Effect of Ionic Presence on Chlorine Disinfection of Animal Viruses.
S. Cronier, P.V. Scarpino, C. Wells (USA)

S13. Interactive Water Quality Simulation of the Han River using Computer Graphics.
Y. Chung, P.N. French, P. Loucks (Korea, USA)

S14. Polyelectrolyte Toxicity Tests by Fish Avoidance Studies.
L.D. Spraggs, R. Gehr, J. Hadjinicolaou (Canada)

S15. Mineralisation Problems in the PWV Complex – The Identification of Viable Solutions by means of a Suite of Deterministic Models.
C.E. Herold (South Africa)

S16. A Chemical Investigation of a marine Sewage Outfall.
P.D. Bartlett, G.A. Eagle (South Africa)

S17. The Location and Nature of Accumulated Phosphorous in Activated Sludge.
L. Buchan (South Africa)

S18. Microbiology of Nutrient Removing Activated Sludge.
Margaret A. Hart, Leah N. Melmed (South Africa)

S19. Nutrient -Salinity Relationships in Four Estuaries of the Cape Province, South Africa.
G.A. Eagle, P.D. Bartlett (South Africa)

S20. The Role of DOC and TOH Measurements in Water Pollution.
R.A. van Steenderen (South Africa)

S21. Aspects of the Performance of Final Clarifiers in the Activated Sludge Process.
C. Davies (South Africa)

S22. Flux of Cadmium through a Laboratory Food Chain (Media-algae-mussel) and its Effects.
H.F.-K.O. Hennig, M.J. Orren (South Africa)

S23. –

S24. The Impact of Diffuse Atmospheric Nutrient Loading on an Oligotrophic Freshwater Lake in a Developing Urban and Industrial Area (Richards Bay, South Africa)
C.G.S. Archibald, M.S. Muller (South Africa)

S25. Interstitial Meiofauna as Indicators of Sandy Beach Pollution.
T.P. McClurg (South Africa)

S26. Production of Algal Protein in Raw Sewage.
J.M.P. Viviers, E. Sandbank, L.R.J. van Vuuren, A. Gerber (South Africa)

S27. The Enumeration of Streptococci and Mycobacteria Present in Landfill leachate.
J.A Donnelly, P.V. Scarpino, D. Brunner (USA)

S28. Some Aspects of the Sensitivity of juvenile *Jasus Lalandii* to the Water Soluble Fraction of Crude Oil.
S.R. Lipschits (South Africa)

S29. Ecotoxicological Evaluation of an Oil Gelling Agent – its Effect on Photosynthesis of Seaweed.
T. Yoshida, T. Maruyama, H. Kojima (Japan)

S30. The Measurement of Organic Pollution of the Sea using Satellite Imagery.
L.V. Shannon, N.M. Walters, A.G.S. Moldan (South Africa)

S31. Exhaustive Recyclic Use of Water in the Food Industries.
R.A. Gallop, A.W. Hydamaka, B.J. Clark, L.B. Carvalho (Canada)

S32. Precipitation of Calcium Phosphate and pH-effects in Denitrifying Biofilms.
E. Arvin, G.H. Kristensen (Denmark)

S33. Biochemical Changes Associated with Luxury Phosphate Uptake in a Modified Phoredox Activated Sludge System.
D.J.J. Potgieter, B.W. Evans (South Africa)

S34. L.F.B. – Full Scale Operation.
D.S. Render (South Africa)

S35. Suppression of Density Waves in Clarifiers.
M.C. Murphy, R.R. Hudgins, P.L. Silveston (Canada)

S36 Parasites in Southern United States Sludges and Disinfection by Standard Sludge Treatment
R.S. Reismers, M.D. Little, A.J. Englande, D.B. Leftwich, D.D. Bowman, R.F. Wilkinson (USA)

S37 Water and Wastewater Treatment with Reusable Magnetite Participles.
N.J. Anderson, B.A. Bolto, D.R. Dixon, L.O. Kolarik, A.J. Priestley, W.G.C. Raper (Australia)

S38. A System Developed for the Treatment of Tanning and Fellmongery Effluents.
S.D. Roets (SA)

S39 Research into the Mass Culture of Algae in Closed Systems.
R.D. Walmsley, S.N. Shillinglaw, D. Geldenhuys (SA)

S40. Utilization of Computerized Water Monitoring and Information System.
E. Ottmann (FRG)

SPECIAL TECHNICAL VISITS DURING CONFERENCE

Delegates who, on their registration forms, indicated interest in special technical visits during the conference, are requested to report at the 'Special Tours' desk on **Monday 29 March**. They will then be informed of arrangements.

As these visits take place by special arrangement only, it may happen that the timing of a specific visit will not suit all the delegates who expressed interest in participating.

PROGRAMME FOR ACCOMPANYING PERSONS

All registered accompanying persons are entitled to:

- attendance at the opening ceremony, followed by a short drive to Bloubergstrand for lunch.
- attendance at all the social functions. Apart from the banquet these social functions are free of charge.
- free transport between hotels and venues for social functions.

Reservations and payment for sightseeing tours L.1 – L.4 should have been made beforehand.

MONDAY 29 MARCH

08h00	Pick up at GROUP A & B hotels* for Opening Ceremony at Nico Malan Theatre
09h00–10h30	Opening Ceremony
10h30–11h00	Tea/Coffee at Civic Centre
11h00	Depart from Civic Centre for lunch at Blue Peter, Bloubergstrand. Expected time of return to hotels: 15h00

TUESDAY 30 MARCH

09h00	Pick up at GROUP A & B hotels* for Tour L.1 (Wine route)
09h30	Depart from Civic Centre on Tour L.1. Travel via Mitchell's Plain (new housing development where tea will be served), along the False Bay coast to Stellenbosch. Lunch at Lanserac Hotel. Continue tour of Stellenbosch (tea at Oude Libertas) then travel via Hellshoogte mountain pass to Bien Donné (expected time of arrival 17h30) to join conference delegates for South African braaivleis (barbecue).

WEDNESDAY 31 MARCH

09h00	Pick up at GROUP A & B hotels* for Tour L.2 (Mountain Passes)
09h30	Depart Civic Centre on Tour L.2. Travel over Du Toit's Kloof pass (tea at Protea Park in the pass). Continue to Worcester (lunch at Kleinplasie). Proceed via Villiersdorp and Elgin to Sir Lowry's Pass. Tea at Van Riebeeck, Gordon's Bay. Expected time of arrival at hotels: 17h30.

THURSDAY 1 APRIL

09h00	Pick up at GROUP A & B hotels* for Tour L.3 (Kirstenbosch)
09h30	Depart Civic Centre on Tour L.3. Visit Kirstenbosch botanical gardens where tea will be served. Proceed to Groot Constantia homestead. Expected time of return to hotels: 13h00

FRIDAY 2 APRIL

09h00	Pick up at GROUP A & B hotels* for Tour L.4 (Cape Point).
09h30	Depart Civic Centre on Tour L.4. Travel via Hout Bay (tea at Suikerbossie) to Chapman's Peak drive, and then via Fishhoek and Simonstown to the Cape of Good Hope Nature Reserve and Cape Point. Return via Kommetjie and the "Old Cape Road" (lunch at Alphen Hotel, Constantia). Expected time of return to hotels 17h00. Those who wish to attend the cheese and wine farewell function (17h35–19h00) can alight at the Civic Centre.

* See timetable for buses, p 22.

SOCIAL FUNCTIONS

All registered delegates and registered accompanying persons are cordially invited to attend the social functions. Apart from the banquet, these social functions are free of charge.

• Sunday 28 March	19h00–20h30	Meet and Greet Reception, Heerengracht Hotel
• Monday 29 March	19h00–20h15	Civic Reception Civic Centre
• Tuesday 30 March	18h00–23h00	Braaivleis (barbecue) at Bien Donné Experimental Farm, Paarl*
• Thursday 1 April	19h30–23h00	Banquet Good Hope Centre (Cost R25 per person)
• Friday 2 April	17h35–19h00	Cheese and Wine Farewell Function, Civic Centre

*NOTE: Weather permitting, this will be an open air function. Comfortable yet warm clothing is therefore indicated. Also note that buses will depart for Bien Donné directly after the technical sessions and that Tour L.1 will conclude at Bien Donné. Suitable clothing arrangements should therefore be made on leaving the hotels in the morning.

POST CONFERENCE SEMINARS

The following post-conference seminars will be held at the Conference Centre of the Council for Scientific and Industrial Research, Pretoria, on 5-6 April 1982.

S.1 Modern trends in sludge management

S.2 Water virology

S.3 Mine water pollution

S.4 Phosphate removal in biological treatment processes

Copies of the full programmes are available on request at the Registration Desk.

TIMETABLE FOR BUSES

NOTES:
1. **Group A hotels in Sea Point Area:** Ambassador, President, Arthur's Seat, Ritz Plaza.
2. **Group B hotels in Upper City Area:** De Waal, Mount Nelson.
3. **Group C hotels in Central City Area:** Town House, Inn-on-the-Square.
4. **Group D hotels in Conference Centre Area:** Capetonian, Tulbagh Square, Heerengracht.
5. Bus transport will NOT be provided during the day-time for Group C and D hotels which are within comfortable walking distance from the Civic Centre.
6. The bus service will be provided at no cost to registered delegates and registered accompanying persons.
7. Although only one time of departure from hotels is given in each instance, this time will not be precise as any specific bus will mostly serve more than one hotel. However, please regard the given times as *the latest time of departure from your hotel* in order to ensure the smooth operation of the bus service.

Sunday 28 March		**HOTELS SERVED**
09h00	Depart from hotels for tours PCT 4 (Cape Point) and PCT 5 (Hermanus)	GROUP A & B
09h30	Depart from Civic Centre on Tours PCT 4 and PCT 5 (expected time of return to hotels : 16h30)	
14h30	Depart from hotels for Civic Centre for tour PCT 3 (Orientation)	GROUP A & B
15h00	Depart from Civic Centre on Tour PCT 3 (expected time of return to hotels : 16h30)	
16h30	Depart from Civic Centre for hotels	GROUP A & B
18h30	Depart from hotels for Meet and Greet function at Heerengracht Hotel	GROUP A & B
20h30	Depart from Heerengracht Hotel to various hotels	GROUP A, B & C

		HOTELS SERVED
Monday 29 March		
08h00	Depart from hotels for registration at Civic Centre and Opening Ceremony at Nico Malan Theatre	GROUP A & B
11h00	Accompanying persons depart from Civic Centre for lunch at Bloubergstrand (expected time of return to hotels : 15h00)	
17h40	Depart from Civic Centre after Technical sessions, for hotels	GROUP A & B
18h45	Depart from hotels for Civic Reception, Civic Centre (concourse)	GROUP A & B
20h30	Depart from Civic Centre for hotels	GROUP A, B & C
Tuesday 30 March		
07h45	Depart from hotels for technical sessions at Civic Centre	GROUP A & B
09h00	Depart from hotels for Tour L.1 (Wine route)	GROUP A & B (Hotel courtesy cars)
09h30	Depart from Civic Centre on Tour L.1. This tour concludes at Bien Donné (expected time 17h30) where group will be joined by delegates for braaivleis (barbecue)	
16h40*	Depart from Civic Centre for braaivleis (barbecue) at Bien Donné (expected arrival 18h00)	
*** NOTE:**	Accompanying persons not participating in Tour L.1, must take this bus to attend the braaivleis (barbecue) at Bien Donné	
21h00 – 23h00	Buses return to hotels as they are filled up by passengers (travelling time about 1 hour)	All Conference hotels

Wednesday 31 March

		HOTELS SERVED
08h00	Depart from hotels for technical tours T1–T6. Delegates will be returned to their hotels after the technical tours.	GROUP A & B
08h30	Depart from Civic Centre on technical tours T1–T6	
09h00	Depart from hotels for Tour L.2 (Mountain Passes)	GROUP A & B (Hotel courtesy cars)
09h30	Depart from Civic Centre on Tour L.2 (expected time of return to hotels : 17h30)	

Thursday 1 April

08h00	Depart from hotels for technical sessions at Civic Centre	GROUP A & B
09h00	Depart from hotels for Tour L.3 (Kirstenbosch)	GROUP A & B (Hotel courtesy cars)
09h30	Depart from Civic Centre on Tour L.3 (expected time of return to hotels : 13h00)	
09h00	Depart from Civic Centre for specially arranged technical visits, and returning at approximately 13h00.	
17h40	Depart from Civic Centre for hotels	GROUP A & B
19h00	Depart from hotels for Conference Banquet at Good Hope Centre, commencing 19h30	GROUP A, B, C & D
23h00	Depart from Good Hope Centre for hotels (expected travelling time: 30 minutes)	GROUP A, B, C & D

Friday 2 April

08h00	Depart from hotels for technical sessions at Civic Centre	GROUP A & B
09h00	Depart from hotels for Tour L.4 (Cape Point)	GROUP A & B (Hotel courtesy cars)

		HOTELS SERVED
09h30*	Depart from Civic Centre on Tour L.4 (expected time of return to hotels : 17h00)	
* NOTE:	Accompanying persons participating in Tour L.4 and who wish to attend the cheese and wine farewell function (17h35–19h00) can alight at the Civic Centre.	
19h00	Depart from Civic Centre after cheese and wine function	GROUP A & B

GENERAL INFORMATION

Members of the Conference Organizing Committee and of the Cape Town Local Committee will be wearing name tags with green and red ribbons respectively. They will be happy to assist delegates whenever possible or refer them to those who can assist them.

REGISTRATION

Registration will take place on the mezzanine level, Civic Centre at the following times:

Sunday 28 March	:	16h00–18h30
Monday 29 March	:	07h30–08h30

Latecomers can register at any time after the Opening Ceremony during the official conference hours.

DAILY LUNCHES AND REFRESHMENTS

Tea/Coffee will be provided free of charge during the periods indicated on the technical programme as well as in the mornings before commencement of the technical sessions.

Lunches R5,00 per meal

Please note that restaurants in the immediate vicinity of the Civic Centre are usually crowded during the lunch hour. Arrangements have therefore been made for lunches to be served to delegates at the Civic Centre concourse tearoom at a cost of R5,00 per head.

Tickets for lunches will be available at the registration desk and MUST be purchased *at least one day in advance* to facilitate catering arrangements.

For the technical visits on Wednesday 31 March, boxed lunches will be provided at no charge.

CAR RENTAL

Car rental services can be provided by AVIS who will have a desk in the registration area.

FIRST AID

The Red Cross will be on hand in the registration area, to provide first aid if this should be required.

PHILATELIC FIRST DAY COVERS

A special first day cover featuring the 11th IAWPR Conference has been printed and can be bought for 60c in the registration area.

INTERPRETATION

Simultaneous interpretation services in English, French and German will be provided in Halls A, B and C during all the technical sessions.

BANKING

Banks at which travellers cheques can be exchanged etc. are situated close to the Civic Centre.

ACCOMMODATION AND TOUR ENQUIRIES

The South African Transport Services, Publicity and Travel Department will have a desk in the registration area to deal with accommodation and tour enquiries

AIR RESERVATIONS

Delegates can obtain assistance with their air reservations at the South African Airways desk in the registration area.

DRESS

Formal dress is not required during the Conference or for the evening functions. Lounge (business) suits will probably be worn by gentlemen attending the conference banquet.

POSTAL FACILITIES

Post boxes and stamp machines are available in the concourse of the Civic Centre.

VENUE FOR SPECIAL MEETINGS

A venue is available at the Civic Centre for groups who wish to arrange special meetings (maximum 30 people). This venue must be reserved beforehand at the registration desk.

NOTICE BOARD

A notice board will be available in the registration area for displaying special messages.

ADDRESS FOR TELEX MESSAGES

The Cape Regional Laboratory of the National Institute for Water Research will receive and relay telex messages to delegates. The telex address is: 57-27819SA.

TELEPHONES

Public telephone booths are available in the Civic Centre concourse.

The telephone numbers for incoming calls are:

Cape Town (021) 21-1392 and 21-1598

ACKNOWLEDGEMENTS

The following organizations have granted generous sponsorships for this conference. Their assistance is gratefully acknowledged by the Conference Organizing Committee and by the South African National Committee of the IAWPR.

AECI Limited
Anglo American Corporation of S A Limited
Chamber of Mines of South Africa
City Council of Cape Town
ISCOR Limited
Klipfontein Organic Products
Mondi Paper Company Limited
Ohlsson's Cape Breweries
Oude Meester Group Limited
SAPPI Limited
SASOL Limited
South African Council for Scientific and Industrial Research
Stellenbosch Farmers' Winery
Water Research Commission

Appreciation is also due to:

Fruit and Fruit Technology Research Institute for arranging and catering for the braaivleis at Bien Donné

Geustyn, Forsyth & Joubert for preparing and publishing the booklet providing technical details of the installations covered by the technical visits T1–T6.

Ninham Shand and Partners Inc. for providing the venue and other services for meetings of the Conference Organizing Committee and the Cape Town Local Committee, and for preparing and publishing the brochure for the Orientation Tour of Cape Town (PCT 3).

The **Red Cross** for being on duty at the Civic Centre during the conference, at no cost.

The following **hosts for technical visits** during and after the conference:

AECI Limited
Bellville Town Council
Cape Town City Council
East Rand Gold and Uranium Company Limited

East Rand Proprietary Mines Limited
Electricity Supply Commission
Institute of Sea Fisheries
Milnerton Town Council
National Institute for Water Research
Paarl Town Council
SAPPI Limited
SASOL II
University of Cape Town

The following organizations which contributed towards the social programme associated with the IAWPR Governing Board meetings prior to the Conference:

Cape Town City Council
Constantia Control Board
Kirsten Farms, Paarl
KWV Limited
Paarl Town Council
Simonsvlei Winery

OFFICE BEARERS

CONFERENCE PRESIDENT: Dr G J Stander

ORGANIZING COMMITTEE:

Mr P E Odendaal	Chairman, Organizing Committee
Mr H Biersch	Chairman, Cape Town Local Committee
Prof A D Carr	Member/University of Cape Town
Dr G G Cillié	Chairman, S A National Committee
Mr P Coombs	Secretary, S A National Committee
Mr S T Fourie	Secretary, Cape Town Local Committee
Mr F Gouws	South African Airways
Mr E J Hall	IAWPR Governing Board Member
Mr K R McCusker	Secretary, Organizing Committee
Mr D W Osborn	Member/City Health Department, Johannesburg
Mr J Panter	South African Transport Services
Mrs M Reeler	Symposium Secretariat, CSIR
Mr W R Ross	Vice-Chairman, Cape Town Local Committee
Mr Minnaar Smit	South African Transport Services
Prof L S Smith	Member/Department of Health
Dr G J Stander	Conference President
Mr A E Thorne	Member/City Engineer's Department, Cape Town
Mr C Visser	South African Transport Services

IAWPR EXECUTIVE

President	Prof R S Engelbrecht, United States of America
Past President	Mr B Hawerman, Sweden

Vice-Presidents	Prof P Harremoës, Denmark Prof E Kuntze, Federal Republic of Germany
Conference President	Dr G J Stander, Republic of South Africa
Chairman, Finance Committee	Mr E J Walder, Australia
Executive Editor	Dr S H Jenkins, United Kingdom
Secretary-Treasurer	Mr Antony Milburn, United Kingdom

CAPE TOWN LOCAL ORGANIZING COMMITTEE

Mr H C Blersch (Chairman)	Ninham Shand and Partners Inc
Mr H G J Beekman	City Engineer's Department, Cape Town
Prof A D Carr	University of Cape Town
Mr J Clarke	Divisional Council of the Cape
Mr S T Fourie	National Institute of Water Research
Mr E P Gouws	Liebenberg and Stander
Mr P J Heydenrych	Hill, Kaplan, Scott and Partners
Mr G E Hoppe	Hawkins, Hawkins and Osborn
Mr J Krige	Geustyn, Forsyth and Joubert
Mr B D Leslie	Ninham Shand and Partners Inc
Mr W M Malan	University of Stellenbosch
Dr R H Marks	R H Marks and Associates
Mr W R Ross	National Institute of Water Research
Prof L S Smith	Department of Health
Mr A E Thorne	City Engineer's Department, Cape Town

LADIES COMMITTEE

Mrs T Blersch
Mrs H Clarke
Mrs D Leslie
Mrs S Ross

APPENDIX II

UNITED STATES OF AMERICA NATIONAL COMMITTEE
For representation of the United States to the
INTERNATIONAL ASSOCIATION ON WATER POLLUTION RESEARCH

CHAIRMAN
DR. FRED G. POHLAND (A.E.E.P.)
SCHOOL OF CIVIL ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332
(404) 894-2268

VICE-CHAIRMAN
DR. RICHARD S. ENGELBRECHT (W.P.C.F.)
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URBANA, ILLINOIS 61801
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SECRETARY-TREASURER
MR. RICHARD A. CONWAY (A.S.C.E.)
RESEARCH & DEVELOPMENT DEPARTMENT
UNION CARBIDE CORPORATION
P. O. BOX 8361
SOUTH CHARLESTON, WEST VIRGINIA 25303
(304) 747-4016

January 29, 1982

TO:

FROM: F. G. Pohland, Chairman, USANC Fred Pohland

RE: Development of Report for EPA on IAWPR Cape Town Conference

I have been informed by the London Office of IAWPR that you have been invited to participate in the IAWPR International Conference at Cape Town, March 29 through April 2, 1982 in the following capacity:

As a result, I am assuming that you will be in attendance at this conference.

Under separate grants from EPA, USANC has prepared reports on the developments of the Sydney (1976), Stockholm (1978) and Toronto (1980) IAWPR International Conferences. In each case, U.S. participants in the respective conferences contributed to the report. It is intended that a similar type report be prepared for EPA on the Cape Town Conference under a grant from EPA. The purpose of this letter is to assess your interest in participating in this USANC activity as a contributor to the report. Fifty (50) U.S. participants in the Cape Town Conference have been identified; however, only 30 can be accommodated as contributors to the report and receive financial reimbursement from the EPA grant (assuming it is awarded).

The report will be an interpretive analysis of the formal and informal happenings and developments at the Conference, not just a collection of papers or abstracts. Rather, the report is to be a critical assessment of the merit of the different presentations at the Conference, together with an evaluation of the floor discussion associated with each presentation. Information gathered informally having relevance to global water pollution research developments will also be included in the report.

Contributors to the report will be responsible for intensively covering some assigned portion of the Conference. This will involve not only attendance at an assigned session but informal conversations with authors and other Conference participants so as to develop unique insights beyond the content of the proceedings. Contributors to the report should also be alert to developments

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ASSOCIATION OF ENVIRONMENTAL **AMERICAN CHEMICAL SOCIETY**
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of a research nature outside of the technical or poster sessions of the Conference. Shortly after the Conference, each contributor will submit a concise (typically 6 to 10 typed pages) report covering the pertinent developments at his/her assigned session and other observations made at the Conference. If you are selected to contribute to the report, more specific information on the intended nature of the overall report and on individual report requirements will be forwarded to you before the Conference.

Contributors to the report will be reimbursed for some of their expenses and services. It should be pointed out that the purpose of the EPA grant to USANC is to prepare the report outlined above; it is not a travel grant. In fact, reimbursement for international travel, i.e., that portion of your travel to Cape Town and return to U.S., will not be allowed. However, contributors will be reimbursed for a portion of their services. The amount of reimbursement will depend on the number of contributors and the funds available but should be adequate to cover a good portion of the expenses associated with attending the Conference.

Please complete and return the enclosed form, indicating your interest in contributing to the proposed report and the technical session you would like to be assigned. In the interest of objectivity, please do not select sessions in which you are a participant. A copy of the Cape Town Conference program is attached.

This memorandum is being sent to only one author per paper. In the case of multiple authorship, this mailing is being forwarded to the author who I presume will be making the presentation at Cape Town or for whom I have an address. If I have misdirected the memorandum, please forward it and the attached questionnaire to whomever will actually be making the presentation at Cape Town. It is necessary, because of limited funds, to solicit only one author per paper as a potential contributor to the report.

If I do not hear from you by February 15, 1982, I shall assume that you are not interested in participating in the preparation of the report. If you have any question, please telephone me at (404) 894-2265.

hb
Attachments

QUESTIONNAIRE

Concerning Participation in Preparation of
Proposed USANC Report for EPA on

DEVELOPMENTS AT ELEVENTH INTERNATIONAL CONFERENCE ON WATER POLLUTION RESEARCH

Cape Town, South Africa

March 29-April 2, 1982

1. I shall be a participant in the IAWPR Conference in Cape Town in the following capacity(ies):

   _____Presenting Paper or Poster Number_____.

   _____Invited Discusser of Paper Number_____.

   _____Chairman of Session _____ on _______________ at _______________.
   Hall date time

   _____Recorder of Session _____ on _______________ at _______________.
   Hall date time

2. I (do) (do not) wish to participate in developing the proposed report to EPA.

3. If you wish to participate in developing the proposed report to EPA, complete the next page relative to the session you are interested in covering.

4. I (would) (would not) like to receive a copy of the USANC report covering the 1980 Toronto IAWPR Conference (supply limited).

5. Name ______________________________

   Mailing Address ______________________________

   ____

   ____

   Phone ______________________

   Date ______________________

____
Signature

PLEASE COMPLETE AND MAIL SO AS TO REACH:

F. G. Pohland
School of Civil Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

BY FEBRUARY 15, 1982

USANC Name _______________________ ,

6. Indicate the sessions of most interest to you by priority, i.e., 1, 2, and 3.

Priority	Session
	MONDAY, 29 MARCH
_____	*Hall A, 11:45 am - 12:30 pm (Paper 1)
_____	**Hall B, 11:45 am - 12:30 pm (Paper 2)
_____	***Hall C, 11:45 am - 12:30 pm (Paper 3)
_____	*Hall A, 2:00 pm - 5:30 pm (Papers Nos. 4, 7, 10, 13)
_____	**Hall B, 2:00 pm - 5:30 pm (Papers Nos. 5, 8, 11, 14)
_____	***Hall C, 2:00 pm - 5:30 pm (Papers Nos. 6, 9, 12, 15)
	TUESDAY, 30 MARCH
_____	Hall A, 9:00 am - 12:30 pm (Papers Nos. 16, 18, 20, 22)
_____	Hall B, 9:00 am - 12:30 pm (Papers Nos. 17, 19, 21, 23)
_____	Hall C, 9:00 am - 12:30 pm (Theme 1)
_____	Hall A, 2:00 pm - 5:30 pm (Papers Nos. 24, 26, 28, 30)
_____	Hall B, 2:00 pm - 5:30 pm (Papers Nos. 25, 27, 29, 31)
_____	Hall C, 2:00 pm - 5:30 pm (Theme 2)
	THURSDAY, 1 APRIL
_____	Hall A, 9:00 am - 12:30 pm (Papers Nos. 32, 34, 36, 38)
_____	Hall B, 9:00 am - 12:30 pm (Papers Nos. 33, 35, 37, 39)
_____	Hall C, 9:00 am - 12:30 pm (Theme 3)
_____	Hall A, 2:00 pm - 5:30 pm (Papers Nos. 40, 42, 44, 46)
_____	Hall B, 2:00 pm - 5:30 pm (Papers Nos. 41, 43, 45, 47)
_____	Hall C, 2:00 pm - 5:30 pm (Theme 4)
	FRIDAY, 2 APRIL
_____	Hall A, 9:00 am - 12:30 pm (Papers Nos. 48, 50, 52, 54)
_____	Hall B, 9:00 am - 12:30 pm (Papers Nos. 49, 51, 53, 55)
_____	Hall C, 9:00 am - 12:30 pm (Theme 5)
_____	Hall A, 2:00 am - 5:30 pm (Papers Nos. 56, 58, 60, 62)
_____	Hall B, 2:00 am - 5:30 pm (Papers Nos. 57, 59, 61, 63)
_____	Hall C, 2:00 am - 5:30 pm (Theme 6)

*Same person should review both sessions.
**Same person should review both sessions.
***Same person should review both sessions.

APPENDIX III

ASSIGNMENTS

Participants in USANC Project

TECHNICAL PRESENTATIONS

DATE/ TIME	Hall A	Hall B	Hall C
March 29 11:45- 5:35	B. H. Olson Papers 1,4,7,10,13	W. C. Boyle Papers 2,5,8,11,14	J. B. Andelman Papers 3,6,9,12,15
March 30 8:30-12:05	E. J. Massaro Papers 16,18,20,22	E. S. K. Chian Papers 17,19,21,23	P. J. Roberts Theme 1 Workshop
12:35- 4:35	P. V. Scarpino Papers 24,26,28,30	D. Roy Papers 25,27,29,31	L. H. Keith Theme 2 Workshop
April 1 9:00-12:35	A. J. Englande Papers 32,34,36,38	D. Jenkins Papers 33,35,37,39	C. Guarino Theme 3 Workshop
1:15- 5:35	G. H. Rohlich Papers 40,42,44,46	F. B. DeWalle Papers 4,43,45,47	A. Netzer Theme 4 Workshop
April 2 9:00-12:35	R. D. Neufeld Papers 48,50,52,54	A. H. Molof Papers 49,51,53,55	K. Kawata Theme 5 Workshop
2:00- 5:35	J. P. Gould Papers 56,58,60,62	P. L. Bishop Papers 57,59,61,63	R. D. Heaton Theme 6 Workshop

POSTER PRESENTATIONS

Name	Poster Presentations
G. Belfort	S4, S11, S12, S22, S27
B. A. Bell	S5, S6, S21, S26, S31
R. A. Canham	S2, S17, S23, S32, S33, S34
T. H. Goodgame	S7, S8, S9, S10, S28, S29
K. D. Lindstedt	S35, S36, S37, S38, S39, S40
H. C. Pruel	S13, S16, S19, S20, S24, S30
C. W. Randall	S1, S3, S14, S15, S18, S25

EDITORS

Executive Editors (Coordinating Subcommittee)

F. G. Pohland
R. A. Conway
R. S. Engelbrecht
D. Stephan

Editors

E. R. Baumann
R. I. Dick
F. M. Saunders
O. J. Sproul

APPENDIX IV

UNITED STATES OF AMERICA NATIONAL COMMITTEE
For representation of the United States to the
INTERNATIONAL ASSOCIATION ON WATER POLLUTION RESEARCH

CHAIRMAN
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RESEARCH & DEVELOPMENT DEPARTMENT
UNION CARBIDE CORPORATION
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SOUTH CHARLESTON, WEST VIRGINIA 25303
(304) 747-4016

MEMORANDUM

DATE: February 28, 1982

TO:

FROM: F. G. Pohland, Chairman

SUBJECT: Assignments for Development of USANC Report on Cape Town Conference

In anticipation that USANC's proposal for developing the Cape Town Conference report will be funded, it is necessary to move ahead in implementing the project.

The Coordinating Subcommittee for preparing USANC's analysis of developments at the IAWPR Conference in Cape Town has assigned sessions to be covered by participants in the project. Your assignment is to prepare a penetrating analysis of developments at the following:

Formal Sessions:

Date ______________________________

Hall ______________________________

Time ______________________________

Poster Presentations:

The Subcommittee regrets that the expressed preferences of all participants for particular sessions could not be accommodated.

SPONSORING ORGANIZATIONS

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11TH INTERNATIONAL CONFERENCE ON WATER POLLUTION RESEARCH, CAPE TOWN, SA, 29 MARCH-2 APRIL 1982

It is essential that you contact one of the members of the USANC Coordinating Subcommittee soon after you arrive in Cape Town. The purpose is to verify your presence and to learn of any necessary changes in assignments.

The members of the Subcommittee are:

Frederick G. Pohland
Richard S. Engelbrecht
David G. Stephan
Richard A. Conway
E. Robert Baumann

Guidelines for preparation of individual reports are enclosed. Inasmuch as each individual's report will appear in the overall project report, it is essential that the guidelines be followed closely. Note particularly the deadline (July 1, 1982) for submission of reports; to achieve maximum value, the report must be submitted soon after the Conference.

It is emphasized that each individual's report is to be an interpretive analysis of developments at the Conference. Proceedings, including discussions, will be published by IAWPR, and these will serve as an objective record of the technical details presented at the Conference. Your report need not, therefore, include the detailed information that will be contained in the Conference Proceedings. What is needed for the USANC report is an assessment of the significance of the presentations and information related to the presentations which will not be found in the Conference Proceedings. Such information might, for example, come from personal discussions with authors or contributors to discussions or poster presentations. For those of you who have participated in the preparation of our prior reports, please note that the outline for individual reports has been modified.

In addition to coverage of the assigned session, participants are specifically requested to report pertinent developments at the Conference which do not occur during the formal presentations (see Section VI of the outline for individual reports). Enclosed is the entire section of the report on the 1980 Conference which concerned developments outside of the technical or poster sessions. Please look it over to gain an idea of the type of information desired. It is felt that this section is unusually important and provides a unique flavor to this series of USANC reports. It is hoped that this section of the report on the Cape Town Conference can be expanded over that for our previous efforts. Remember, information presented during the poster sessions probably will not be published intact and therefore requires special attention and coverage.

Information on compensation for services and expenses is included in the guidelines. Experience with previous reports has required implementation of rigid financial motivations for submission of reports prior to the deadline; please note the deadline for submission of reports. You should also be aware that the Internal Revenue Service has regulations on deducting personal expenses for attending foreign conferences; this information can be obtained from the IRS.

GUIDELINES

for

PREPARATION OF INDIVIDUAL REPORTS

on

DEVELOPMENTS AT THE ELEVENTH INTERNATIONAL CONFERENCE ON WATER POLLUTION RESEARCH

CAPE TOWN, SOUTH AFRICA

March 29 - April 2, 1982

Emphasis of Report

USANC's report on developments at the IAWPR Conference in Cape Town is not intended to be simply a record of the Conference. Instead, an interpretive analysis of significant developments at the Conference is required. This penetrating assessment is to be developed not only by critical analysis of papers and formal and informal discussions at the technical and poster sessions, but also by inclusion of insights gained through more informal contacts with Conference participants.

The positive aspects of Conference developments should be emphasized (what did you learn that is important to United States water pollution research activities?). Don't dwell on criticism of papers which you feel to be inferior, and don't give much space to papers which are not pertinent to problems in the Unites States. Don't include information of limited significance such as how many people attended a session, how well the session chairman performed, etc.

Distribution

The report will be distributed at least within EPA, to USANC Sponsoring Organizations and USANC committee members, and to participants in the report development. The report also will be made available to the public through the National Technical Information Service; its availability will be announced through notices in publications of USANC's Sponsoring Organizations.

Length

Individual reports on sessions are to be as short or long as necessary to adequately describe pertinent developments. It is not necessary to give equal attention to each paper or poster. Space in the report should be allocated on the basis of relevance to U. S. water pollution control problems and water pollution research activities. It is anticipated that the average length of individual reports will be a tightly written 6 to 10 double-spaced pages, but don't unnecessarily expand or condense a concise, penetrating report merely to achieve that length.

Format

The organization and content of the individual reports is to be as indicated in the outline included as Attachment I. Note that the last section of the report provides an opportunity to record observations which do not relate to your assignment and that it should begin on a separate sheet of paper. These contributions from all participants will be combined.

Metric units should be used, and the editorial standards for Water Research (included as Attachment II) should be observed.

It is hoped that arrangements can be made to record the English translation of each technical session; thus, it may be possible to provide cassette tapes of assigned sessions following the Conference.

Submission

Individual reports are to be submitted in double-spaced typed finished form. Four copies of the report are to be postmarked no later than July 1, 1982 and addressed to:

F. G. Pohland
School of Civil Engineering
Georgia Institute of Technology
Atlanta, GA 30332

Prompt submission of reports is essential. As indicated in the following section, reimbursement for late reports will be at a reduced level and no reimbursement will be made for reports postmarked after July 15, 1982.

Compensation

Compensation will require a submitted statement for services and expenses and, as stated above, reimbursement will be contingent upon postmarking of an acceptable report prior to the deadline. No reimbursement for international travel can be allowed. A maximum level of reimbursement will be established based on available funds, cost sharing requirements, and demands on available funds. Furthermore, because the maximum allowable level of compensation will depend on the magnitude of the total requests for compensation, no payments can be made until all reports are approved (one late individual could hold up all payments). Requests for reimbursement are to be sent to the USANC Secretary-Treasurer, Richard A. Conway, Union Carbide Corporation, P. O. Box 8361 (770-342), South Charleston, WV 25303. Use the expense voucher included as Attachment III for this purpose.

Reimbursement for acceptable reports postmarked after July 1, 1982, will be reduced by 50 percent. No reimbursement will be made for reports postmarked after July 15, 1982.

Coordinating Subcommittee

Development of these guidelines, review and acceptance of individual reports and preparation of the final EPA report is being coordinated by a USA National Committee Coordinating Subcommittee consisting of:

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Additional information concerning this USANC activity may be obtained from any of the Subcommittee members.

ATTACHMENT I

OUTLINE FOR INDIVIDUAL REPORTS ON DEVELOPMENTS AT CAPE TOWN IAWPR CONFERENCE

*I. SESSION

*A. Day, Hall, Time

*B. Theme of Session (a few words describing the major orientation of papers - e.g., "Marine Disposal" or "Sludge Thickening and Dewatering")

*II. REVIEWER

*A. Name

*B. Position and Affiliation

*III. DESCRIPTION OF SESSION PAPERS OR POSTERS

(Paper-by-paper summary, starting with identification, author's or reviewer's abstract, followed by highlights of the formal presentations, prepared discussions and floor discussions. For poster papers, use same format but include as a separate report.)

*IV. CRITIQUE OF SESSION

(Observations and commentary regarding the session and its papers including insights developed outside of the meeting room, possible sources of additional information, and critical review of the papers and the session, indicating matters such as how the research reports were received, their originality and quality, etc.)

*V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

(How might the reported results be applied to solve U.S. water pollution problems? What research pertinent to U.S. needs is suggested by the reported research?)

*VI. INFORMATION AND OBSERVATIONS FROM THE CONFERENCE RELEVANT TO U.S. WATER POLLUTION RESEARCH BUT UNRELATED TO ASSIGNED SESSION

(For example, information on water pollution-related developments which was not presented at any of the formal sessions at the Conference, information on emerging problems or on research-in-progress which may be of particular importance.) See "Illustrative Contributions from Assigned Session" attached.

NOTE: Section VI will be separated from the remainder of the individual reports - begin on a separate sheet which includes your name.

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*These headings are to be contained in each report.

ATTACHMENT II

SCRIPT REQUIREMENTS

1. An original typed copy in double spacing and two copies should be submitted. The text must be ready for printing, and any substantial changes in proof other than typographical errors may be charged to the authors.

2. Half-tone illustrations should be restricted to the minimum necessary and the photographs may be on glossy not matte paper, enlarged sufficiently to permit their clear reproduction in half-tone. These must accompany the manuscript, preferably mounted on separate sheets. If words or numbers appear on photographs two copies are requested, one clearly printed and the other without inscription. If line drawings are already well drawn, it may be possible to reproduce them direct from the original, but in this case it is essential that the original drawings or good photo-prints should be provided. It is not possible to reproduce from "dyeline" prints or from prints with weak lines, and illustrations for reproduction should normally be about twice the final size required. All illustrations should be provided with descriptive legends and the illustrations should accompany manuscripts separately, with legends typed on a separate sheet. The manuscript and diagrams will be discarded one month after publication unless the publisher is requested to return original material to the author.

3. In the interests of economy and in order to avoid the introduction of errors, tables will be reproduced by photo-offset means directly from the authors' manuscripts.

(a) Look at current Tables in the Journal, and arrange your spatial layout of the Table to conform.

(b) Type should be clear and even, either on an electric typewriter with a carbon ribbon, or LETRASET.

(c) Tables, headings and legends should be typed on a separate sheet.

(d) Insert rules.

(e) Words normally italicized should be typed in italics or underlined.

4. References to published literature should be quoted in the text as follows: Smith (1950)—the date of publication, in parentheses, following the author's name. References should be listed together at the end of each paper and not given as footnotes. They should be arranged in alphabetical order (first author's surname) with the name of the periodical abbreviated in the style of the *World List of Scientific Periodicals* (4th edn, Butterworths, London, 1963–1965, 3 vols) and appear as follows:

Fermi E. and Marshall L. (1947) On the interaction between neutrons and electrons. *Phys. Rev.* 72, 1139–1146.
Thring M. W. (1957) *Air Pollution*, p. 132. Butterworths, London.

It is particularly requested that (a) authors' initials (b) title of the paper and (c) the volume or part numbers and page numbers both beginning and end are given in every case.

5. Papers should be without unnecessary historical introduction.

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best available copy.

ATTACHMENT III

USANC REIMBURSEMENT REQUEST

Expenses incurred relating to preparation of interpretive analysis of the 11th Biennial International Water Pollution Control Conference, Cape Town, South Africa, March 29 - April 2, 1982. The first column should show the total cost of developing the report including your services and expenses - the information is needed for cost sharing calculations. Show in the second column the actual reimbursement requested. Leave the third column blank.

ITEM	(1) AMOUNT	(2) REIMBURSEMENT REQUESTED	(3) REIMBURSEMENT APPROVED
Professional Services (collection/ assimilation/analysis of information, report preparation, etc.) _____days @ $________per day*			
Conference Registration (~$182)**			
Subsistence during Conference** (Hotel and meals) _____days @ $57 per day			
Travel Costs** Air: - Within U.S. - International*** Personal Auto - Within U.S. _____miles @ 20¢ per mile			
Miscellaneous (Please itemize) - Limousine, cab fare - - (no rental cars, no secretarial)			

*Indicate days claimed and consulting rate per day (USANC will set a maximum).
**Attach Conference registration, hotel and air travel receipts.
***International Travel is considered to be from U.S. city of embarkation to Cape Town and return to the U.S.; include amount in column (1) only.

Send this voucher to:

Richard A. Conway
Research and Development
Union Carbide Corporation
P. O. Box 8361 (770-342)
South Charleston, WV 25303

____
Signature

____
Social Security

____
Date of Submission

FOR COORDINATING SUBCOMMITTEE USE ONLY:

Date and Amount Paid ________________

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